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## Summary

Research performed under the current grant covered four several distinct, but related topics. The first topic was a theoretical and empirical examination of the taxonomic structure of Perceptual Speed abilities, both in general, in the context of predictive validities for task performance, given the importance of Perceptual Speed abilities for determining individual differences in performance at intermediate levels of skill acquisition. The second topic extended previous work by Ackerman and Kanfer on the determinants of individual differences in skill acquisition by examining individual differences in performance after extended practice (i.e., asymptotic skill levels), and by examining individual differences in performance during a non-practice retention period (of one month). A third concern of this research program pertained to the integration of ability and non-ability predictors of individual differences in skill acquisition (and accompanying variables such as self-efficacy and task self-confidence). Finally, using the theory and empirical data obtained in previous Air Force sponsored research and the current program, interactions between aptitudes and instructional treatments were examined.

## Table of Contents

<i>Section</i>	<i>Page</i>
I. Introduction . . . . .	1
II. Current Research . . . . .	1
A. Perceptual Speed Abilities . . . . .	2
B. Individual Differences in Asymptotic Skills and Skill Retention . . . . .	6
C. Ability and Non-Ability Trait Determinants of Skill Acquisition . . . . .	12
D. Aptitude - Treatment Interactions (ATIs) . . . . .	27
III. General Discussion/Conclusions . . . . .	31
IV. References . . . . .	34
V. Publications during the grant period . . . . .	36
Ackerman, P. L., & Woltz, D.J. (1994) [ <i>Journal of Educational Psychology</i> ] . .	36
Ackerman, P. L., Kanfer, R., & Goff, M. (1995) [ <i>Journal of Experimental Psychology: Applied</i> ] . . . . .	36
Ackerman, P. L. (1996) [ <i>Intelligence</i> ] . . . . .	37
Goska, R. E., & Ackerman, P. L. (1996) [ <i>Journal of Educational Psychology</i> ] .	37
Kanfer, R., & Ackerman, P. L. (1996) [ <i>Cognitive Interference</i> ] . . . . .	38
Rolfhus, E. L., & Ackerman, P. L. (1996) [ <i>Journal of Educational Psychology</i> ] .	39
Ackerman, P. L. (In press) [ <i>Journal of Personality</i> ] . . . . .	39
Ackerman, P. L., & Heggstad, E. D. (In press) [ <i>Psychological Bulletin</i> ] . . . .	40
VI. Presentations during the grant period . . . . .	41

## I. Introduction

Over the past decade, we have embarked on a series of theoretical and empirical investigations that focus on the cognitive ability and motivational/self-regulatory determinants of individual differences in skill acquisition and skilled performance. In particular, through work sponsored in part by the Air Force Office of Scientific Research, we have developed and provided initial empirical validations of theoretical approaches to the cognitive ability determinants of individual differences in skill acquisition (e.g., Ackerman, 1988, 1990), and to motivational and ability interactions in skill acquisition (e.g., Kanfer & Ackerman, 1989, 1996; Kanfer et al., 1994). We have also extended these perspectives to the prediction of performance in highly complex tasks, such as a high-fidelity air traffic controller simulation task (e.g., Ackerman, 1992; Ackerman & Kanfer, 1993a). Such work has had both basic research implications as well as application utility in military and civilian sectors (e.g., see Ackerman & Kanfer, 1993b). Our broad goals in the current research program were to extend the ability and motivational/self-regulatory perspectives to a wider variety of task situations, and to more fully examine the basic constructs underlying the theoretical perspectives. This report provides a summary of the research program, as we worked toward these two main goals. In general, our perspectives were supported by the various empirical studies we conducted. In addition, several new insights were obtained, especially through investigation of individual differences in skill acquisition under conditions of extended practice, conditions of skill retention over a one-month period of time, and in examination of both aptitude-treatment interactions, and trait relations across cognitive ability, motivation, personality, and self-concept domains.

## II. Current Research

Research performed under the current grant covered four several distinct, but related topics. The first topic was a theoretical and empirical examination of the taxonomic structure of Perceptual Speed abilities, both in general, in the context of predictive validities for task performance, given the importance of Perceptual Speed abilities for determining individual differences in performance at intermediate levels of skill acquisition. This work is reviewed in *Section A: Perceptual Speed Abilities*. The second topic extended our previous work on the determinants of individual differences in skill acquisition by examining individual differences in performance after extended practice (i.e., asymptotic skill levels), and by examining individual differences in performance during a non-practice retention period (of one month). These studies are reviewed in *Section B: Individual Differences in Asymptotic Skills and Skill Retention*. A third concern of this research program pertained to the integration of ability and non-ability predictors of individual differences in skill acquisition (and accompanying variables such as self-efficacy and task self-confidence). Studies associated with these issues are reviewed in *Section C: Ability and Non-Ability Trait Determinants of Skill Acquisition*. Finally, using the theory and empirical data obtained in our previous AFOSR sponsored research and the current program, interactions between aptitudes and instructional treatments were examined. These studies are reviewed in *Section D. Aptitude - Treatment Interactions*. Each of these sections is presented in turn, below.



*A. Perceptual Speed Abilities.* In our previous work (e.g., Ackerman, 1988; Ackerman, 1990, 1992), it became clear that Perceptual Speed abilities play an important role in determining individual differences in task performance during learning and skill acquisition, especially at the intermediate stages of learning -- when the learner has already acquired the basics of task performance, but seeks to improve or streamline the routines for accomplishing task goals. Because very little was known about the nature and structure of Perceptual Speed abilities, we set two objectives toward an in-depth examination of these abilities.

The first objective was to construct a provisional taxonomy of Perceptual Speed abilities (see Ackerman, 1990). The second objective was to empirically explore much of the taxonomic representation of Perceptual Speed abilities, both in general, and in the context of predicting individual differences in performance during learning and skill acquisition. The provisional taxonomy identified seven possible dimensions along which Perceptual Speed abilities might differ, as follows:

1. Item content (i.e., spatial, verbal, numerical)
2. Consistency of stimulus-response mappings (e.g., consistent versus varied mapping of stimuli and responses)
3. Item novelty and item difficulty
4. Precision (of encoding and of responding)
5. Modality (of encoding and of responding)
6. Memory demands (low, medium, high)
7. Degree of scanning versus single items (with no scanning)

The next step was to construct the empirical examination of Perceptual Speed abilities -- by drawing on as many of the different dimensions of the taxonomy as was practical, and incorporating learning tasks against which the tests could be evaluated. The study and results are briefly described below.

Tests. For this study, we created multiple versions of 13 new Perceptual Speed tests -- designed to sample from the following 5 dimensions: (Item Content, Consistency, Item Novelty, Memory Demands, and Scanning). The tests were as follows (broken out by the first dimension -- Item Content):

#### Verbal

1. Finding A & T (Consistent/Familiar -- scan for instances of "A" and "T" in Italian text)
2. Finding Y and E (Consistent/Novel -- same as Finding A & T, except text was random symbols)
3. Name Comparison (Verbal -- identical name comparison)

#### Spatial

4. Naming Symbols (Spatial/Verbal - Consistent -- write in single letter code for 5

- different simple figures)
5. Pursuit (Spatial -- visually trace lines in background of other curving lines)
  6. Canceling Symbols (Spatial - Consistent -- scan page for a single target figure among other simple target figures)

#### Numerical

7. Summing to 10 (Numerical - Consistent -- Circle pairs of numbers if they sum to 10)
8. Number Sorting (Numerical - Find the largest of 5 large numbers)
9. Factors of 7 (Numerical - Consistent -- Circle 2-digit numbers if they are exactly divisible by 7)
10. Number Comparison (Numerical -- identical number comparison)

#### Mixed Content

11. Coding Test (Verbal/Number Memory -- lookup a letter or number code for common words)
12. Mirror Reading (Verbal/Spatial -- find target words written in mirrored text)
13. Digit/Symbol (Memory/Spatial/Numerical -- put numbers next to symbols corresponding to lookup key)

In addition, we also assessed performance on 6 off-the-shelf Perceptual Speed ability tests, as follows:

14. Differential Aptitude Battery - Clerical Speed and Accuracy Test (Verbal: letters and scanning)
15. Guilford-Zimmerman Perceptual Speed Test (Spatial: Identical pictures scanning)
16. Clerical Abilities 2 (CA-2) (Verbal/Numerical: Table lookup)
17. Letter/Number Substitution (Memory and Verbal/Numerical)
18. Directional Headings Test (Verbal/Spatial/ Numerical integration)
19. Scattered X's (Verbal scanning)

We also obtained test scores on several reference cognitive ability tests, and Perceptual/Motor reaction time (RT) tests, as follows:

#### Verbal

1. Verbal Analogies Test
2. Word Beginnings Test
3. Vocabulary
4. Controlled Associations

#### Spatial

5. Paper Folding
6. Spatial Analogies
7. Spatial Orientation
8. Verbal Test of Spatial Ability

### Numerical

9. Math Knowledge
10. Number Series
11. Subtraction and Multiplication
12. Math Word Problem Solving

### Perceptual/Motor Reaction Time (RT)

13. 9 Choice Reaction Time
14. 4 Choice Reaction Time
15. 2 Choice Reaction Time
16. Simple Reaction Time

Finally, to provide criterion reference scores, we gave the learners extended practice on two versions of the Noun-Pair lookup task (see Ackerman & Woltz, 1994, for additional task details):

### Criterion Tasks

1. Noun-Pair Consistent Mapping (CM) (Verbal/ Memory -- Visually lookup or recall word pairs). 75 blocks of 18 trials = 1,350 trials
2. Noun-Pair Varied Mapping (VM) (Verbal/Scanning -- visually lookup word pairs). 40 Blocks of 18 trials = 720 trials.

Procedure. A sample of 110 undergraduate students (between 18-30 years old) participated in the study. The study was conducted in 10 hours of testing over the course of a week.

Results. The first set of results focused on practice effects for the 13 Perceptual Speed tests that were provided with extended practice. As predicted, tests with consistent mapping of stimuli and responses showed substantial and significant practice effects (as large as a mean performance improvement of 3.1 standard deviation units (in the Coding test), in contrast to the tests with varied mapping of stimuli and responses (as little as 0.1 standard deviation unit improvement in means). Clearly, the consistency of mapping in the tests had an impact on the effect of practice on test performance. No other dimensional breakout yielded a similar coherence of practice effect results.

A second analysis examined the relations between Perceptual Speed tests on the one hand (at initial performance and after 10 trials of practice) and performance on the Perceptual/Motor Reaction Time (RT) tests on the other. According to our earlier research (Ackerman, 1990), it was predicted that, with practice, individual differences on consistently mapped Perceptual Speed ability tests would more closely resemble individual differences in Perceptual/Motor RT abilities. Although the findings were somewhat weaker than with the mean performance over practice results, the consistency breakout was again supported.

The third set of analyses examined intercorrelations of test scores -- both among just the Perceptual Speed tests, and in a larger framework, among both the Perceptual Speed tests and the reference ability battery (that included spatial, verbal, numerical, and Perceptual/Motor RT abilities). The factor analysis of only the 19 Perceptual Speed tests (along with the two Noun-Pair criterion tasks) yielded an oblique three-factor solution. The tests aligned along factors identified as: I. Pattern Identification, II. Scanning/Lookup and III. Memory. These factors were all correlated with one another (median  $r$  between factors = .57) -- implying a second-order general Perceptual Speed factor in addition to these first-order, or "primary" Perceptual Speed factor. Similarly, the larger factor analysis (including reference ability tests) showed that 11 of the 19 Perceptual Speed tests, while all having significant loadings on a broad Perceptual Speed ability factor, also had salient loadings on one or another of the four content/reference factors (verbal, spatial, numerical, and Perceptual/Motor RT).

The forth, and final, set of analyses was designed to evaluate the utility of the taxonomic dimensions for predicting individual differences in performance of the two Noun-Pair lookup criterion tasks. Based on the earlier analyses, three different sets of Perceptual Speed composites were created:

1. Perceptual Speed (PS) Ability by Content (PS-General, PS-Verbal, PS-Spatial, PS-Numerical)
2. Perceptual Speed Ability by Consistency of Stimulus-Response Mapping (Consistent Mapping, Varied Mapping)
3. Perceptual Speed Ability by Types of Processing (Pattern Recognition, Scanning, Memory)

Then, each of the sets of composite scores was examined against the sequence of practice trials for the consistent and varied versions of the Noun-Pair task. The first analysis (by content) only showed a minimal discrimination among the criterion tasks or among practice trials within tasks. (Only PS-Numerical showed a demonstrably lower correlation than the other three composites with criterion task performance on both Noun-Pair tasks.) The second analysis (by consistency) did show discriminations both by task type and by practice. The PS-Consistent composite correlated highest with late practice trials on the consistent version of the Noun-Pair task, and the PS-Varied showed higher correlations with initial performance on the consistent version of the Noun-Pair task, and with all trials on the varied version of the Noun-Pair task. These differences, while in the predicted patterns, were not large. The third analysis (by type of processing) was much more substantial. The PS-Scanning composite was highly correlated throughout practice on the varied version of the Noun-Pair task (median  $r$  = .68), correlated highly with initial performance on the consistent version of the Noun-Pair task ( $r$  = .66), and the correlation declined with practice (at the end of 1,350 trials,  $r$  = .51). In contrast, the PS-Memory composite correlated modestly with the varied mapping version of the Noun-Pair task (median  $r$  = .50), and showed an

increasing pattern of correlations across practice on the consistent version ( $r = .64$  at the end of practice). The PS-Pattern Recognition composite showed generally lower, and stable correlations with both versions of the Noun-Pair task.

Conclusions. This first large-scale study of the taxonomic representation of Perceptual Speed abilities was highly successful in delineating the coherence (from a construct validity perspective) and utility (from a differential predictive validity standpoint) of the hypothesized dimensions of Perceptual Speed abilities -- specifically: Item Content, Consistency of Stimulus-Response mappings, and a complex dimension of Memory/Scanning/Pattern Recognition categories. This research is continuing, and we expect to more fully explore and validate the remaining dimensions of Perceptual Speed abilities in the context of the current project on Perceptual Speed and Psychomotor abilities ("Psychomotor and Perceptual Abilities and Skilled Performance," AFOSR F49620-96-1-0065, Phillip L. Ackerman, Principal Investigator)

### *B. Individual Differences in Asymptotic Skills and Skill Retention*

#### Prediction of Individual Differences in Asymptotic Skills

Design. The study designed to assess asymptotic skills was a straightforward extension of our previous work. Using the Kanfer-Ackerman Air Traffic Control (K-A ATC Task),<sup>1</sup> and a sample of 166 University of Minnesota undergraduate students, we provided nearly twice as much practice as had been accorded learners in our previous studies (36 10-minute trials). We also administered a battery of ability and non-ability predictors measures. The ability battery included 14 tests to assess five reference ability factors (Verbal, Spatial, Numerical, Perceptual Speed, and Perceptual/Motor RT). The non-ability measures included assessments of Personality, Vocational Interests, and Self-Concept.

Results. The most striking aspect of the criterion task (the K-A ATC Task) data were the substantial changes in performance among the participants over the course of the six hours of time-on-task practice. For the first three trials, mean Time-to-Land-One-Plane (abbreviated RT) was 16.45 sec., with a between-subjects standard deviation of 4.74 sec. For the last three trials, mean RT was 8.66 sec., with a between-subjects standard deviation of 0.89 sec (very close to the machine-cycle time of 7.5 sec/plane). That is, extended practice on the K-A ATC task resulted in an overall 47% decrease in mean RT, but a massive reduction in the magnitude of individual differences in task performance (a decrease in between-subject standard deviations of 81%). The reduction in between-subject variability presumably makes it more difficult to predict variance in asymptotic task performance -- because there is simply less between-subject variance to-be-predicted.

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<sup>1</sup> The Kanfer-Ackerman Air Traffic Controller Task© program is copyrighted software by Ruth Kanfer, Phillip L. Ackerman, and Kim A. Pearson, University of Minnesota.

Examination of ability-performance relations showed (as predicted from the Ackerman, 1988; 1990 theory), that broad content abilities (Spatial/Mechanical and Verbal) well predict early K-A ATC task performance (around  $r = .4$ ), but decline in correlation over practice. On the other hand, both Mathematical Ability (mostly computation) and Perceptual Speed ability showed stable correlations across the entire set of practice trials. Finally, as also predicted from the theory, Perceptual/Motor RT abilities show initially modest correlations with performance (around  $r = .25$ ), but increased in predictive validity over practice, with the highest correlations shown for late asymptotic practiced performance (around  $r = .40$ ), *even in the face of the substantial reduction of between-subject variance in performance*. That is, by combining all of the predictor measures (content abilities best predicting early task performance and Perceptual/Motor RT measures best predicting asymptotic task performance), multiple regressions showed that each phase of learning task performance was equally well accounted for by ability predictors ( $R = .42$  for the first three task trials and  $R = .45$  for the final three task trials). These results, taken together, provide substantial validation of Ackerman's (1988) theory of the cognitive ability determinants of individual differences in task performance. In addition, such results again point to the important ramifications of choosing the appropriate measures for predicting performance of different phases of skill acquisition. A set of tests that are optimally predictive of early task performance (e.g., in training) are not likely to represent the optimal predictors of late (or asymptotic task performance (e.g., on-the-job).

Gender Differences. A sufficient sampling of both men and women in the study allowed for an exploration of gender differences in K-A ATC task performance, and also allowed for examination of differential ability - performance and non-ability - performance relations over the course of extended task practice. As we had seen in previous studies, early performance differences were obtained, with the male average performance on the K-A ATC task exceeding that of the females (initial Mean RT for males = 15.38 sec, for females Mean RT = 17.42 sec.). By the end of extended practice, though, the mean differences between groups were very small (Mean RT = 8.53 sec. vs. 8.77 sec, for males and females, respectively). However, which abilities were most predictive of task performance differentiated by gender. For males, Mathematical ability was more highly predictive of task performance throughout practice. For females, Spatial/Mechanical, Verbal, and Perceptual Speed abilities were more predictive of performance, especially in early task trials. In contrast, Perceptual/Motor RT abilities were highly related to late task performance for both gender groups. Together, these results appear to indicate that men and women depend on different abilities in acquiring the basic strategies for early task performance -- but that as task rules and procedures are automatized, both genders depend on the same Perceptual/Motor abilities to accomplish task performance. Additional differences were observed in some of the non-ability predictors of performance for men and women. Specifically, for women, vocational interests and personality factors showed increasing correlations across task practice, while a concomitant pattern was not found for men. Although only tentative conclusions can be made from this single investigation, it appeared that good performance by women learners was more dependent on their standing on Conscientiousness factor, while for men, good performance may have been more associated



with a specific task interest. Nonetheless, these data indicate that gender-based cognitive styles may be important determinants of training success, especially for tasks that have high demands for spatial abilities and Perceptual/Motor speed.

### Prediction of Individual Differences in Skill Retention

We completed another large-scale study that explicitly focused on two major issues -- individual differences in skill acquisition and retention and non-ability predictors. The segments of the study that mainly concern the non-ability measures are described in Kanfer, Ackerman and Heggstad (1996) and reviewed in section "2. C." below. Here we discuss the findings associated with abilities, performance, and skill retention.

Procedure and Measures. A sample of 158 undergraduate students (between 18-30) participated in the acquisition phase of the study. One month later, 150 of the participants returned for the retention phase of the study (a loss of only 5% of the sample due to attrition). The acquisition phase of the study lasted 15 hours over five sessions. Session 1 was devoted to ability assessment (including tests of Spatial, Mathematical, Perceptual Speed, and Perceptual/Motor RT abilities). Session 2 was devoted to assessment of non-ability traits (e.g., Personality, Motivation, Interests, Self-Concept, Motivational Skills) and to viewing an instructional video for the complex air traffic controller simulation task (Terminal Radar Approach Control TRACON®).<sup>2</sup> Session 3 had three hours of TRACON acquisition practice. Session 4 had three hours of K-A ATC acquisition practice, and Session 5 had three hours of Noun-Pair Lookup task practice (including two hours of practice on the consistent mapping version and an hour of practice on the varied mapping version of the task).

Four weeks later, the participants returned to the laboratory and completed two sessions of retention performance assessment, across all four tasks: TRACON, K-A ATC, CM Noun-Pair and VM Noun-Pair.

Results - Means. There is quite a lot of data obtained from this study -- and we are still processing various aspects of the data base. However, several major features of the results can be described here. First, retention was generally quite good in all four of the tasks. While performance declined somewhat in all four tasks, see **Figure 1** mean differences between the last acquisition trial (or groups of trials) was significant and substantial in the two highly consistent tasks K-A ATC ( $\bar{M}_{\text{acquisition}} = 57.0$  planes landed,  $\bar{M}_{\text{retention}} = 51.9$  planes landed,  $t = 10.72$ ,  $p < .01$ ); and CM Noun-Pair ( $\bar{M}_{\text{acquisition}} = 887$  ms,  $\bar{M}_{\text{retention}} = 1301$  ms,  $t = 21.35$ ,  $p < .01$ ). In contrast, performance differences were nonsignificant or marginally significant (but clearly much smaller in magnitude) for the tasks with the greatest demands on controlled information processing, namely: TRACON ( $\bar{M}_{\text{acquisition}} = 10.1$  planes handled,  $\bar{M}_{\text{retention}} = 9.8$  planes handled,  $t = 1.20$ , ns); and VM Noun-Pair ( $\bar{M}_{\text{acquisition}} = 1973$  ms,  $\bar{M}_{\text{retention}} = 2005$  ms,  $t = 1.88$ ,  $p = .06$ ).

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<sup>2</sup> TRACON® is licensed software by Wesson International, Austin, TX.



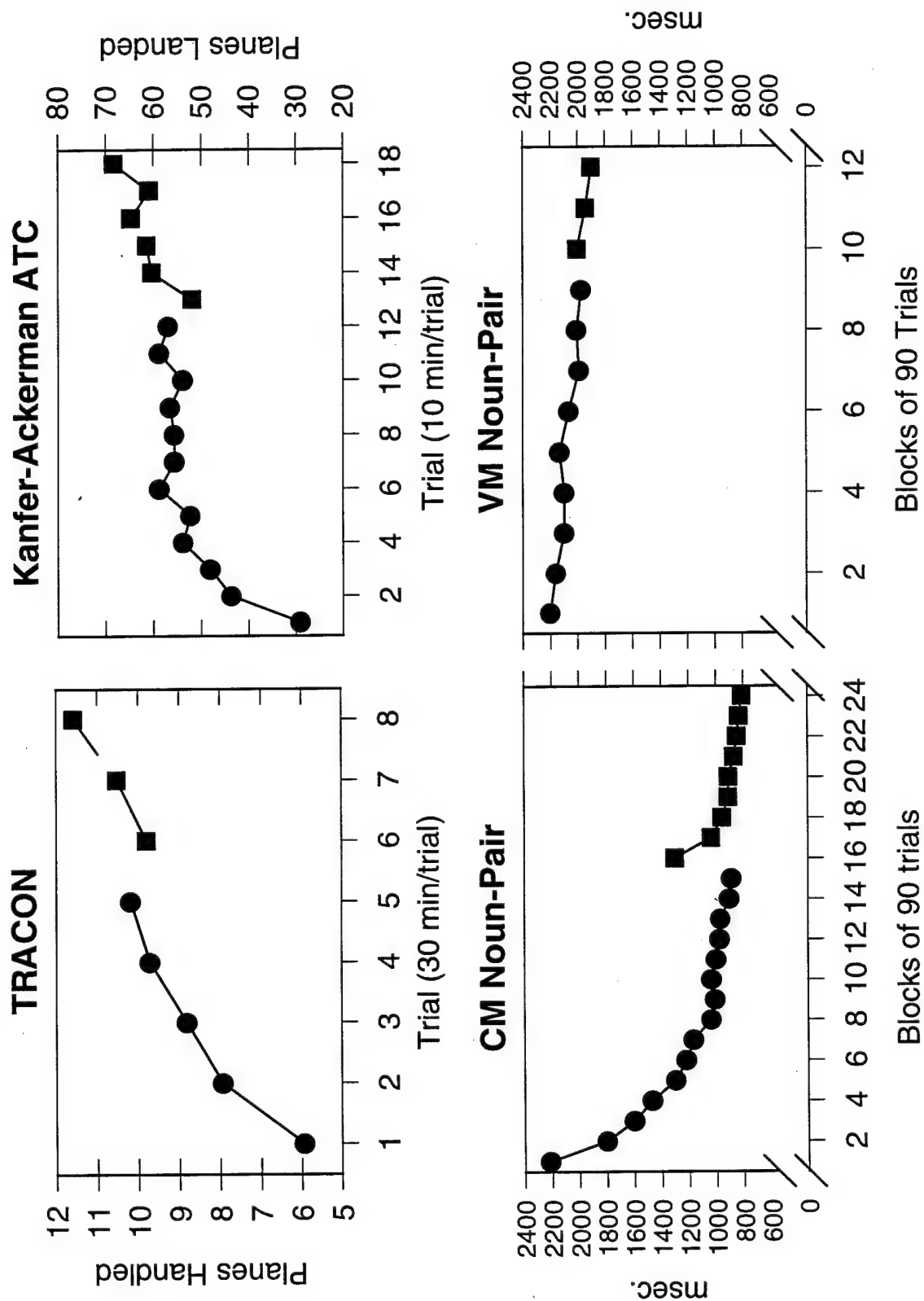


Figure 1. Mean performance on four criterion tasks, as a function of acquisition practice and retention practice. Tasks are TRACON, Kanfer Ackerman ATC Task, and Noun-Pair Lookup Task (Consistent and Varied Mapping).

Results - Ability-Performance Relations. From our research perspective, the most critical sources of information obtained in this study were the data concerning two aspects of performance -- the ability-performance associations for acquisition and retention, and the relations between initial task acquisition performance, final task acquisition performance, and retention performance. That is, we sought to answer the question of which ability and task performance variables best predict individual differences in performance after a one-month retention interval. To answer this question, the most straightforward means available was to use path analysis (with the LISREL software program), with ability measures (composites of a general cognitive ability, "g," a composite for Perceptual Speed Ability, and a composite for Perceptual/Motor RT ability) as predictors, and initial acquisition performance scores, final acquisition performance scores, and retention scores as criteria. Illustration of the path-analytic results with respective path coefficients is presented in **Figure 2** for all four tasks.

After deletion of non-significant paths, the models showed excellent fit statistics, according to standard methods for assessing adequacy of models. The model for TRACON performance, upper left panel, yielded  $X^2(5) = 3.95$ ,  $p = .56$ , GFI = .99, NFI = .99, and NNFI = 1.01. The model for K-A ATC performance, upper right panel, yielded  $X^2(4) = 1.14$ ,  $p = .89$ , GFI = 1.00, NFI = 1.00, and NNFI = 1.02. The model for CM Noun-Pair performance, lower left panel, yielded  $X^2(4) = 1.77$ ,  $p = .78$ , GFI = 1.00, NFI = .99, and NNFI = 1.04. The model for VM Noun-Pair performance, lower right panel, yielded  $X^2(4) = 0.87$ ,  $p = .65$ , GFI = 1.00, NFI = 1.00, and NNFI = 1.02.

Examination of the path models shows differences between the different tasks, dependent on the kinds of processing required of the learners. For TRACON, general ability (g) was instrumental in predicting initial acquisition performance, final acquisition performance, and retention performance. Perceptual Speed and Perceptual/Motor RT abilities were significant only in predicting initial acquisition performance on TRACON. However, Trial 1 performance on TRACON was not instrumental in predicting retention performance, while the last acquisition trial performance was most highly related to the retention trial -- indicating that individual differences in retention were mainly related to general ability and to the level of performance obtained at the end of the acquisition phase.

In contrast, the K-A ATC task showed an influence of general ability only at the first trial of the acquisition phase, Perceptual Speed was only significantly related to the last acquisition trial, and Perceptual/Motor RT was unrelated to performance at any phase (this final result is concordant with our earlier studies -- in that Perceptual/Motor RT is most highly associated with highly practiced performance, and at the first retention trial, learners had only performed 12 10-minute task trials). An additional aspect of these data that we consider to be quite important, was that Trial 1 acquisition performance added significantly to the prediction of the first retention trial performance, indicating that some of the abilities/skills used for initial task acquisition are the same as those required for remembering how to perform the task after a one-month retention interval. Such results are directly contradictory of the simplex-based theories of individual differences in skilled performance (e.g., Humphreys, 1968), and are concordant with our theory of the ability determinants of skill acquisition (Ackerman, 1988, 1990).

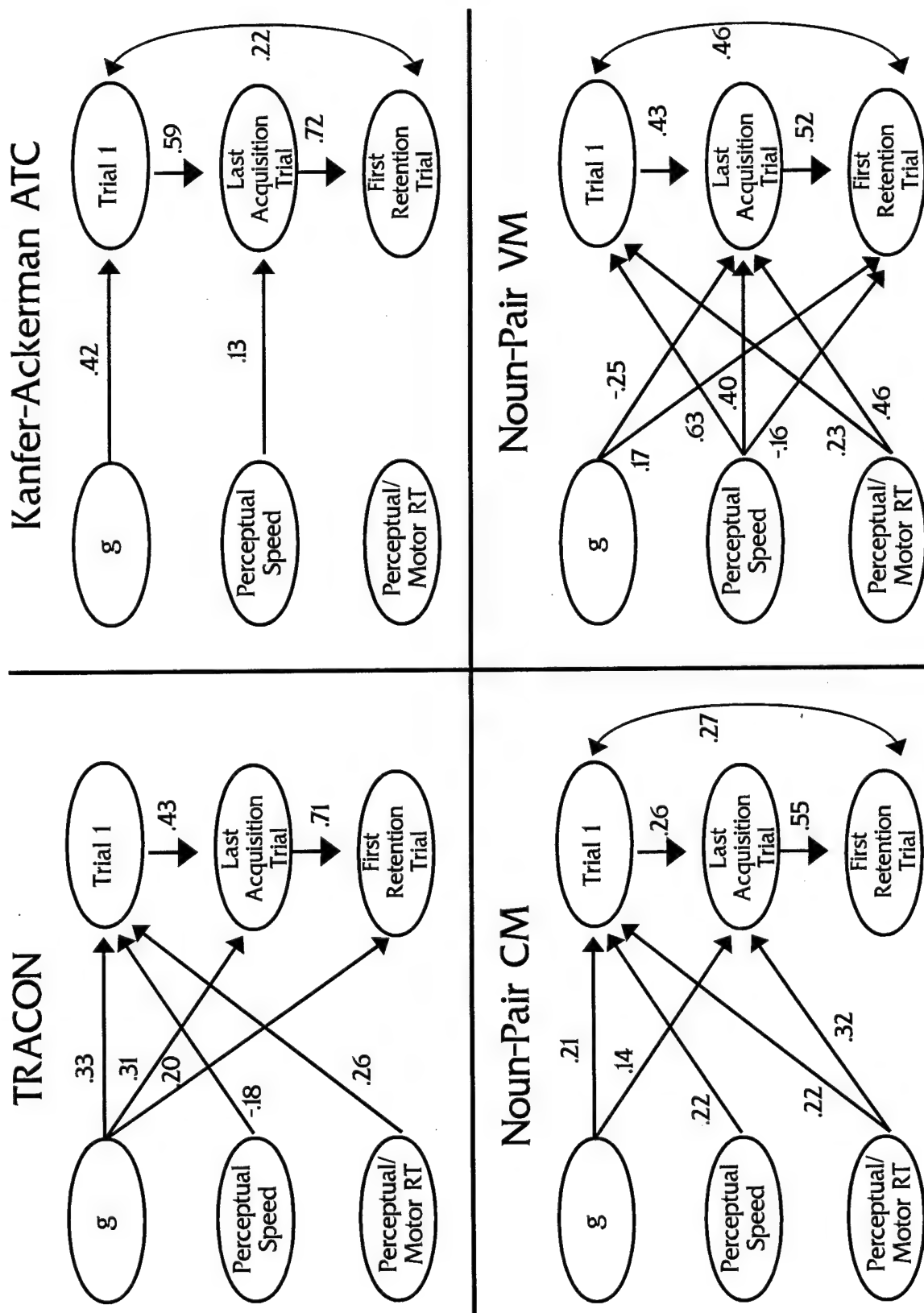


Figure 2. LISREL derived path analysis solutions for initial acquisition practice and retention. Tasks are: TRACON (Terminal Radar Approach Control), Kanfer-Ackerman ATC, and Noun-Pair Lookup Task (CM = Consistent Mapping, VM = Varied Mapping). Ability composites are: "g" = General Ability, Perceptual Speed, and Perceptual/Motor Reaction Time (RT).

Similar results were found for the two Noun-Pair tasks. In both cases, Trial 1 acquisition phase had a significant path to the first retention trial performance. However, consistent with earlier interpretations of Noun-Pair task requirements (e.g., Ackerman & Woltz, 1994), the CM task requires General abilities at initial performance and at the last acquisition trial, while Perceptual Speed has a greater role in predicting performance in the VM task, at both acquisition and retention phases of the study.

Overall, these are strong results in support of our approach to the ability determinants of skill acquisition -- and they carry-over to a relatively modest retention interval (one month). Future research should be devoted to examining the role of abilities and individual differences in initial performance as they relate to individual differences in retention after longer intervals, and also after a greater degree of skill acquisition.

### *C. Ability and Non-Ability Trait Determinants of Skill Acquisition*

Two studies make up the major sources of data concerning both ability and non-ability determinants of individual differences in skill acquisition. These studies are reported in detail in Ackerman, Kanfer and Goff (1995) and in Kanfer, Ackerman, and Heggestad (1996). A brief review of the major findings from these studies is provided here.

Cognitive and Non-Cognitive Determinants and Consequences of Complex Skill Acquisition. This experiment contains four major categories of measures: Distal individual differences measures; Proximal individual differences measures; Concomitant Proximal measures; and Criterion (TRACON) task performance measures.

1. *Distal Measures.* (Distal refers to measures that are general and are typically thought to represent trait constructs). Numerous distal measures were administered, in order to converge on the multiple determinants of performance in the TRACON simulation task. The measures were designed to assess individual differences in cognitive/intellectual abilities, personality, vocational interests and self-ratings of ability and self-concept (along with a short measure of Motivational Skills). In addition, the Dial Reading Test and a companion test (the Directional Headings Test) were administered to evaluate whether these measures assess common variance among ability and non-ability influences on performance.
2. *Proximal Measures.* (Proximal refers to measures that are task-specific, and are associated with a particular situational context.) A questionnaire (Interim Questionnaire) was administered one or two days *after* trainees had viewed the instructions for performing TRACON, and just *prior to* actual task engagement. This questionnaire assessed Negative Motivation and Positive Motivation thoughts directly pertaining to the TRACON task, and several aspects of task-specific Self-Efficacy. (This questionnaire was also administered prior to each subsequent TRACON session)
3. *Concomitant/Proximal Measures.* Two types of concomitant measures were used

during TRACON practice, an Interim Questionnaire (administered just prior to the beginning of each TRACON session) and a Task Perceptions Questionnaire (administered just after each TRACON session). Both measures assessed task-specific thoughts, retrospective and prospective. Retrospective thought frequency for the Interim Questionnaire pertained to intrusive (Negative Motivation) and purposeful (Positive Motivation) thought frequency during the days between TRACON sessions. For the Task Perceptions Questionnaire, retrospective thoughts pertained to the 6 simulation trials in the just-completed session. Prospective thoughts pertained to TRACON task self-efficacy (both measures), and performance expectancies.

4. *Task Performance Measures.* As in previous studies (Ackerman, 1992; Ackerman & Kanfer 1993b), the major measures used to assess performance in TRACON relate to the number of planes successfully handled (carried to final disposition) during each simulation. Overall performance is measured, as are separate performance components of handling arrival flights and overflights.

General ability-performance results: The experiment supported three main conclusions about the relations between abilities and performance on TRACON, as follows:

1. Performance throughout practice is well-predicted by measures of cognitive and intellectual ability. The measures most highly associated with task performance were Spatial, Math and Perceptual Speed abilities. Verbal ability showed only a modest validity for predicting performance on TRACON, at any stage of practice.
2. Across practice, ability measures accounted for nearly 50% of the individual differences variance in TRACON performance.
3. Arrival and Overflight components of TRACON performance showed substantial and equivalent ability demands early in practice, but with practice, spatial and math abilities were more predictive of arrival than overflight components. In contrast, Perceptual Speed abilities showed generally stable correlations with both arrivals and overflights across practice.

#### Distal and Proximal Non-Ability Measures and Performance

Personality. Personality constructs have often been implicated in determinations of stress-reactivity or stress-resistance in performance contexts (e.g., see Vickers, 1991). We first correlated measures of the five major personality composites with overall performance on TRACON. None of the correlations reached traditional levels of significance: Neuroticism  $r = -.15$ , Extroversion  $r = -.02$ , Openness  $r = -.01$ , Agreeableness  $r = .02$ , Conscientiousness  $r = .02$ , TIE  $r = -.03$ , and Anxiety  $r = -.19$ . A multiple regression with these seven composites similarly yielded no significant result,  $R = .24$ , or  $R^2 = .06$ . Simple correlations between personality composites and daily session measures of TRACON yielded similar results, as did separate correlations for arrivals and overflights. (Only

Anxiety revealed a significant correlation with performance, and only for Session 1 --  $r = -.28, p < .01$ .)

Vocational Interests. It has often been claimed in the vocational literature that emotional stress is generated when a mismatch exists between an individual's vocational interests and the task that the individual is asked to perform (see, e.g., Dawis & Lofquist, 1984). We computed correlations between theme-scales of the UNIACT and aggregate TRACON performance, with the following results: Realistic  $r = .31$ , Investigative  $r = .19$ , Artistic  $r = -.14$ , Social  $r = -.07$ , Enterprising  $r = -.07$ , and Conventional  $r = .07$ . The correlations between the Realistic and Investigative theme-scales and performance are the only ones that reached both statistical and practical significance, jointly accounting for about 10% of the variance in TRACON performance ( $R = .31, F(2,90) = 4.90, p < .01$ ).

Self-Ratings of Ability and Self-Concept. The three composite scales of ability self-ratings and the eight measures of academic/ability self-concept were factor analyzed to yield three main composites. The first composite (SR1) was comprised of items from math-spatial- mechanical- and science- self-concept, and self-ratings of similar abilities. The second composite (SR2) was comprised of items from verbal self-concept and self-ratings of general verbal ability and more specific reading, vocabulary, and writing abilities. The third composite (SR3) was comprised of items from self-management- clerical- and stress-resistant self-concept, and self-ratings of self-control and coping abilities. Correlations between these three composites and TRACON performance indicated that the first composite was highly and consistently related to performance (mean  $r = .46$ ), and the remaining two composites were essentially unrelated to TRACON performance (SR2: mean  $r = -.08$ ; SR3: mean  $r = .12$ ). These results indicate that selected self-ratings of ability and academic/ability self-concept are effective predictors of performance in a complex task. In the aggregate, these measures accounted for 24% of the overall variance in TRACON ( $R = .49, F(3,87) = 9.10, p < .01$ ). In particular, the self-ratings of math, spatial, and mechanical abilities accounted for about 20% of the variance in TRACON performance across practice sessions.

Motivational Skills. As in previous studies (Ackerman & Kanfer, 1993b), an 18-item measure of Motivational Skills was included in this study. Consistent with results from predicting success in air traffic control tasks (both in the laboratory and in the field with Federal Aviation Administration air traffic controller trainees), the Motivational Skills measure showed consistent, modest and significant correlations with performance across all sessions of TRACON performance (mean  $r = .25$ ). For aggregate performance, the correlation with Motivational Skills was  $r = .27, p < .01$ , or about 7% of the variance.

Proximal Measures. Measures of *proximal* thoughts and self-efficacy *prior* to engagement in TRACON performance showed validity for predicting individual differences in task performance. Specifically, greater incidence of Negative Motivation thoughts was significantly and substantially associated with lower TRACON performance throughout practice, and to a somewhat smaller degree, greater incidence of Positive Motivation thoughts was significantly associated with positive TRACON performance throughout

practice. Also, higher levels of self-efficacy (especially as perceived in comparison with other college students), were associated with TRACON performance.

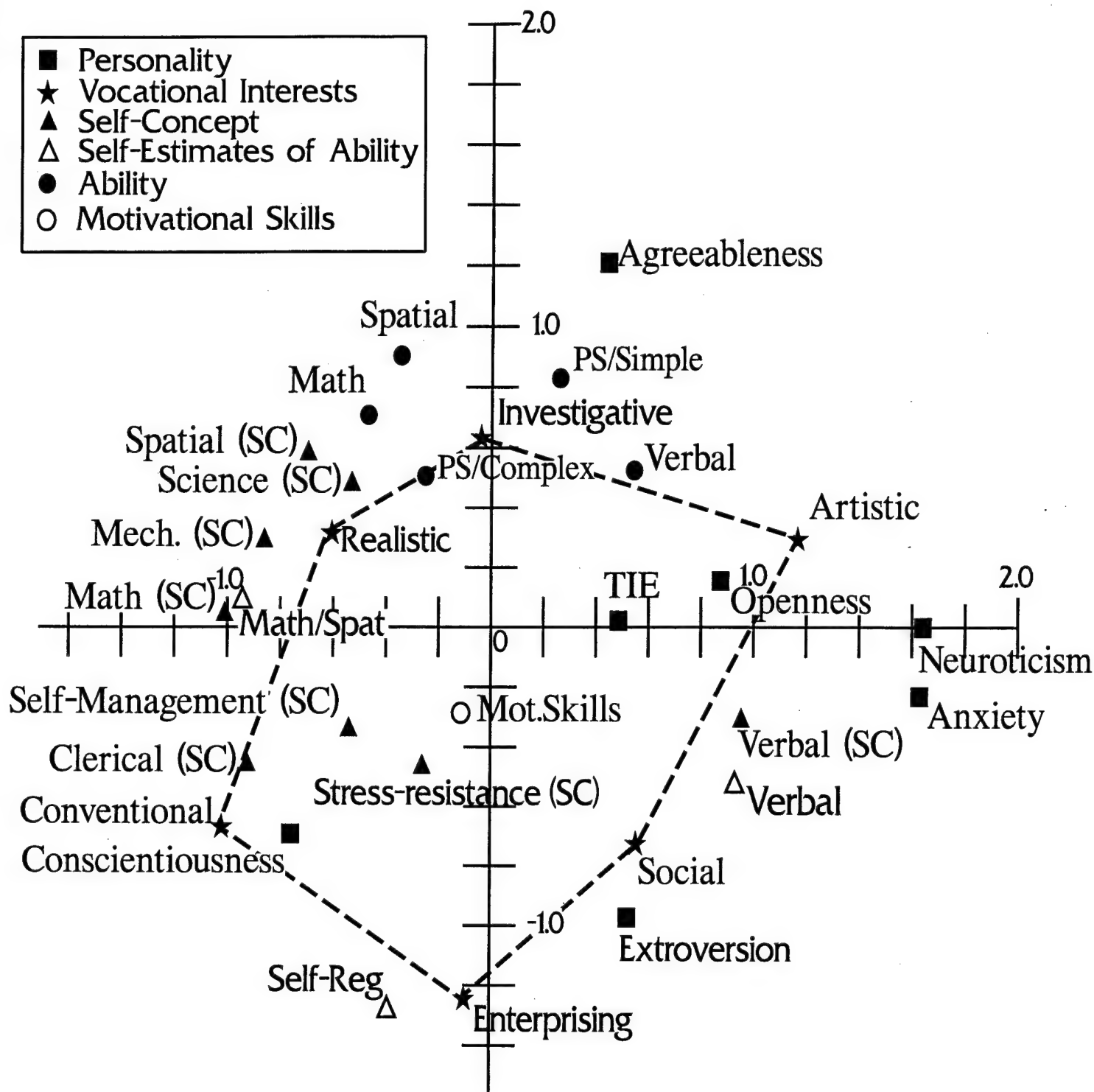
### Broad Analysis of the Predictor Space

Based on the wide array of distal measures we administered in this study, the discussion in the literature on the general nature of the predictor space (e.g., Kanfer et al., 1995), and the above findings that are indicative of communality among several families of predictor measures, we decided to focus more specifically on the predictor space. We adopted a radex-type approach (e.g., see Ackerman, 1988 and Marshalek, Lohman, and Snow, 1983 for examples) and used a multidimensional scaling technique.

Although personality variables did not show individual or incremental validity for predicting TRACON performance, there is a broader interest in evaluating the communality of personality and other distal constructs, such as ability and vocational interests. We thus included personality with the other distal measures for this analysis. In keeping with the radex approach, correlations serve as proxies for similarity estimates. Intercorrelations among the following variables were computed: Personality (7 measures), Vocational Interests (6), Self-Concept (8), Self-ratings of ability (3), Ability (5 composite measures), and the measure of Motivational Skills (1), for a total of 30 variables. (The correlations among these variables are shown in Table 1.) Given that some of the correlations were negative (e.g., among personality measures), a constant (1) was added to all correlations. The matrix was then subjected to KYST-3 multidimensional scaling (MDS) (Kruskal, Young, & Seery, 1973), a two-dimensional solution was extracted (Stress Formula 1 = .20), and as is customary, the solution was rotated to a principal-components orientation. The solution is plotted in **Figure 3**.

There are many interesting similarities and differences in the figure, but we focus on a few similarities that we found to be especially salient. First, the MDS solution recovered the Holland Hexagon structure that is typically found with vocational interest measures (and is explicitly expected from the interest measures). There are several close proximities among interest variables and personality measures (e.g., Social Interests and Extroversion; Artistic Interests and Openness; Conventional Interests and Conscientiousness). In addition, there are other similarities among interests and both non-ability and ability measures: Realistic Interests are close in proximity to Math, Mechanical, and Science Self-Concepts; Enterprising Interests are close to Self-Regulatory self-estimates of ability; and Investigative Interests are close to all five ability measures, but closest to the two Perceptual Speed composites.





**Figure 3.** Non-metric multidimensional scaling (KYST; Kruskal, Seery, & Young, 1973) two-dimensional solution to measures of personality, vocational interests, self-concept, ability self-ratings, and objective ability measures, based on a modified correlation matrix to indicate distances. Variables close to one another represent high positive intercorrelations, whereas variables distant from one another represent negligible or negative intercorrelations. From Ackerman, Kanfer, and Goff (1995).

## Conclusions

Individual differences in performance on a complex skill acquisition task are well-predicted by a variety of distal cognitive and non-cognitive trait measures, including ability, interests, motivational skills, self-concept, and self-ratings of ability. In addition, proximal measures of negative and positive motivational thoughts and self-efficacy were also substantially related to task performance. However, substantial overlap in variance was found among the distal variables, proximal variables, and between distal and proximal variables. By simultaneous examination of these variables in predicting task performance, early and late in practice, we demonstrated that much of the valid criterion-related variance among non-ability predictors was variance that was *shared with cognitive ability variables*. Communalities among the cognitive and non-cognitive determinants of performance, revealed by MDS, suggest that aptitude complexes for skill acquisition can be identified, and in turn, used in an integrated selection program (for a discussion of aptitude complexes, see Snow, 1989). In addition, the demonstrated communalities may provide a further basis for building models of learner - task relations that better represent the interrelations of cognitive and non-cognitive traits. Models that take these cognitive *and* non-cognitive determinants into consideration, may ultimately allow for a joint prediction of the effort allocated to a task, and strategic decisions made by trainees (e.g., choice behaviors that are guided by self-concept or self-efficacy).

The link between ability and non-ability predictors has important implications for broader conceptual issues and for prediction of performance, as follows:

1. For prediction of performance, individual differences in abilities obviously play a key role. Ability measures accounted for roughly 30-45% of the variance in complex task performance over practice. However, an individual's perceptions of these abilities as they relate to diverse domains of behavior may importantly mediate the ability-performance relations in unforeseen ways, particularly when successful performance over time involves emotion control and persistence. That is, while objective ability measures are moderately-to-highly correlated with self-concept and self-estimates of ability, the self-concept measures have a direct influence on negative and positive motivational thoughts and on task self-efficacy. How trainees view their abilities may be important in determining how they confront a novel task, though the objective measures of ability better how well they actually perform the task.

2. Controversy over the association among measures of major personality dimensions and performance has focused on matching personality measures (grounded in theories of personality structure) to the performance (criterion) space. Results of this study suggest another fruitful avenue for resolution of these issues pertains to a broadening of the predictor domain to include measures and concepts from vocational psychology and self-concept theories. In the integrated perspective presented here, self-concept and interest measures represent constructs with important links to broad personality dimensions as well as performance criteria.

3. In applied settings, thorough assessment of individual differences in cognitive abilities is often precluded for a variety of reasons. Individual differences in non-ability predictors may provide a useful partial proxy for such assessments when ability data are unavailable. However, as shown in the present results, when performance is complex and the demands of the task change over practice, such proxy measures may introduce systematic, non-performance related variance into the equation. Indeed, we found gender differences in task self-efficacy, even after variance attributable to ability, self-concept, interests and so on had been removed. It remains to be seen what determines these residual differences in self-efficacy, and whether or not such differences, in turn, influence choice decisions on how to engage the task assignment. It will be important for future investigations to discover the sources of discrepancies between individual differences in task performance and task self-efficacy.

4. Measures typically considered to be ability predictors (such as the Dial Reading and Directional Headings Tests), may indeed capture substantial variance in the non-ability domain. Questions of the relative effectiveness of these measures for determining non-ability variance, compared to self-report non-ability measures depend, of course, on the construct under consideration. However, these initial findings provide a potentially important direction for future research on performance-based assessment of non-ability constructs. In an applied setting, such as job selection, concerns about demand characteristics (e.g., "faking good") on non-ability measures might be circumvented, by administering objective ability tests that tap individual differences in non-ability constructs, given that it is generally impossible to fake good on an ability test. The high validity demonstrated by the Perceptual Speed measure suggested that this particular trait may represent an especially useful addition to more traditional batteries of cognitive abilities in predicting individual differences in performance on complex skill tasks.

#### Motivational Skills & Self-Regulation for Learning: A Trait Perspective

A second study was conducted, partly to replicate the previous results, but also to examine cross-correlations with an extant measure of motivational/self-regulatory skills -- the Motivated Strategies for Learning Questionnaire (MSLQ) (e.g., see Pintrich, Smith, Garcia, & McKeachie, 1993). In addition, as part of the larger study (see earlier discussion of skill retention), we administered measures of ability, personality, interests, self-concept, and self-ratings of ability. We assessed learning and performance in three short tasks -- namely, the TRACON task mentioned in the immediately preceding study (for only 3½ hours of practice), the K-A ATC task (discussed earlier), and the Noun-Pair Lookup task (for additional details, see Ackerman & Woltz, 1994). Finally, we obtained task-specific self efficacy measures for each of these three criterion learning tasks. The sample was composed of 158 undergraduate students at the University of Minnesota.

The MSLQ is described by Pintrich et al. (1993) as containing 15 relatively independent scales -- six are Motivational Scales, and the remaining nine are Learning Strategy scales. Our analysis of the measure proceeded along several lines -- the first was

an attempt to reduce the MSLQ to a few relatively coherent composites. We started with the 15 scales described by Pintrich et al. (1993). A factor analysis of the scales found them to be factorially complex (which is consistent with the results from Pintrich et al.). Thus, the scales could not be easily combined with this technique. A second method was less sophisticated -- that is, to create composites based on the two main themes (Motivation and Learning Strategies), and derive internal consistency reliability estimates. This analysis yielded acceptable results, but for one scale, that of Test Anxiety, which did not fit well in either composite. A unit-weighted z-score composite of the Motivational Scales (without Test Anxiety) yielded Cronbach's  $\alpha = .72$ . Similarly, a unit-weighted z-score composite of the Learning Strategy Scales yielded Cronbach's  $\alpha = .82$ .

In a second stage analysis, we included our measure of Motivational Skills and showed a correlation of  $r = .38$  with the MSLQ Motivational Scales composite, and a smaller correlation of  $r = .28$  with the MSLQ Learning Strategies Scales composite. When we combined the Motivational Skills measure with the MSLQ Motivational Scales composite, Cronbach's  $\alpha$  was essentially unchanged ( $\alpha = .73$ ). We thus ended up with three measures; namely, (1) *A Motivation composite* (a composite of the Motivational Skills measure and five of the MSLQ Motivational Scales), (2) *A Learning Strategy composite* (composed of the nine MSLQ Learning Strategy Scales), and (3) *A Test Anxiety scale*. It should be noted that the first two composites correlated  $r = .48$ , while the Learning Strategy composite correlated with Test Anxiety  $r = -.05$ , and the Motivational Composite correlated with Test Anxiety  $r = -.22$ .

#### Cross-Correlations with other Trait Measures

The examination of convergent and discriminant validity for the Motivation and Learning Strategy composites (and the Test Anxiety Scale) was exploratory, and essentially used a bottom-up approach. We derived correlations between the composites/scale and scales/composites from cognitive, affective, conative, and self-concept domains. Each of these domains will be treated in turn below, and in the context of structural equation modeling. Unless specially noted otherwise, we settled on a 'meaningfulness' criterion of  $r = .3$  to minimize Type I errors.

Ability. One of the first questions to be answered was whether these three measures were significantly correlated with objective measures of ability. To assess these relations, we performed simple correlations with three ability composites from our test battery: Spatial, Math, and Perceptual Speed (for details on the test battery, see Ackerman, et al., 1995 -- where similar measures were administered). Additional correlations were obtained with American College Testing (ACT) composites obtained from academic records. Essentially, there was no substantial overlap between the Motivation and Learning Strategy composites on the one hand, and measures of cognitive ability on the other hand. Only the Test Anxiety Scale showed a substantial (negative) correlation,  $r = -.33$  -- and only with the ACT Science Reasoning composite. A reasonable conclusion is that these self-report measures are not closely aligned with self-knowledge about cognitive abilities.

Personality. In contrast to the ability domain, several areas of overlap were found between personality measures and the Motivation, Learning Strategy, and Test Anxiety measures. Probably the least surprising result (e.g., see review by Hembree, 1988) was the substantial overlap between Test Anxiety and four personality measures generally identified with trait Anxiety and Neuroticism. A negative correlation was found between Test Anxiety and Well-Being, and positive correlations were found with Alienation, Stress, and Neuroticism, all in the  $r = .3$  to  $.4$  range.

The Motivation and Learning Strategies composites showed overlap with measures of Achievement Motivation (called "nAch") (substantial correlations were found for the Learning Strategies composite). Both of these composites also substantially correlated with the Goff & Ackerman (1992) Typical Intellectual Engagement Scale;  $r = .55$  for Motivation and  $r = .40$  for Learning Strategies.

Vocational Interests. Only Investigative (or Intellectual -- see Holland, 1959) vocational interests revealed a substantial correlation with the Motivation composite --  $r = .40$ .

Self-Concept/Self-Ratings of Ability. Two composite measures of self-concept/self-ratings of ability were created (for details, see Ackerman, et al., 1995) -- Math/Spatial Self-Concept (math- spatial- mechanical- and science- self-concept, and self-ratings of similar abilities), and Self-Management Self-Concept (items from self-management self-concept and self-ratings of self-control and verbal abilities). Both the Motivation and Learning Strategy composites showed substantial correlations with the Self-Management Self-Concept composite --  $r = .60$  and  $.53$ , respectively. Neither the Motivation and Learning Strategy composites had correlations that exceeded our  $r = .30$  threshold with Math/Science Self-Concept (nor did Test Anxiety).

Summary. The picture of the Motivation, Learning Strategy, and Test Anxiety composites that emerges from the correlational analysis indicates substantial commonality with traditional trait measures. Test Anxiety appeared to be well captured by standard personality measures of Neuroticism and Stress Reactions. In contrast, the Learning Strategy composite showed substantial commonality with Achievement scales and Self-Management Self-Concept. The Motivation composite was more complex, in that substantial commonality was found across Investigative/Intellectual interests, Typical Intellectual Engagement, and Self-Management Self-Concept. For all intents and purposes, though, no substantial commonality was found with objective ability measures, either administered in the laboratory or during college admissions testing.

#### Task-Specific Self Efficacy

In the context of the three learning tasks, self efficacy measures were administered just after the task instructions, but prior to actual task engagement. The first procedure used the traditional method (see Bandura, 1986) that included 5 items of increasing performance

difficulty. Learners were instructed to rate their confidence in performing at the designated level, using a 10 point scale, ranging from "No confidence" to "Certain that I can do it." Self efficacy for this procedure was calculated as the sum of confidence scores across the five items for each task. A second procedure (which was mainly used to identify the latent variable in later LISREL analyses) was to ask the learner to provide a norm-based assessment of his/her self efficacy. For this procedure, the learner was told:

*I think I will perform better than \_\_\_\_\_ % of a random group of college students (Enter a number between 1 and 99)*

Because this second procedure only involves a single item, and would likely be less reliable than the traditional procedure, we will present the main analyses with respect only to the first procedure. However, correlations between the traditional method and the norm-based method within each task were substantial, though they declined across tasks/task experience ( $r = .76, .52, \text{ and } .44$ , for TRACON, K-A ATC, and Noun-Pair respectively).

#### Cross-Correlations with Self efficacy

The correlations between the trait measures and composites (administered prior to the learning tasks) and the traditional assessment of task-specific self efficacy were investigated for construct overlap. Surprisingly, few measures correlated with self efficacy above our criterion ( $r = .3$ ). For the ability measures, only Spatial and Perceptual Speed abilities correlated substantially with TRACON self efficacy ( $r = .30$  for both). Test Anxiety (from the MSLQ) and Stress [from the Multidimensional Personality Questionnaire (MPQ), Tellegen, 1982] also showed negative correlations with self efficacy ( $r = -.36$  and  $-.32$ , respectively). On the other hand, Math/Spatial Self-Concept showed a much greater correlation with TRACON self efficacy ( $r = .54$ ) (significant differences in correlations for Test Anxiety [ $t(144) = 2.00, p < .05$ ] and for Stress [ $t(144) = 2.48, p < .01$ ]).

For self efficacy on the K-A ATC task, Math/Spatial Self-Concept was the only trait measure that showed a substantial correlation ( $r = .30$ ), though TRACON self efficacy also revealed a significant correlation ( $r = .44$ ). Finally, for self efficacy on the Noun-Pair task, only K-A ATC self efficacy showed a substantial correlation ( $r = .50$ ).

In general, few trait measures showed substantial overlap with task-specific self efficacy. Math/Spatial Self-Concept highly correlated with TRACON self efficacy -- even more highly than the objective ability measures, suggesting that self-estimates of ability and competence may be more influential in determining task-specific self efficacy than a learner's objective ability. This finding is consistent with a previous study (for details see Ackerman, et al., 1995) where a structural model indicated that the path from ability to task-specific self efficacy was *indirect*, that is, the direct paths found were from ability to self-concept and self-concept to task-specific self efficacy.



### Integrated Models and Task-Specific Self Efficacy

Because it is often difficult to integrate many different sources of simple correlations, we attempted to build (in a mostly exploratory fashion) models for predicting self efficacy in each of the three tasks that were examined in the study (namely, TRACON, K-A ATC Task, and the Noun-Pair associative memory task).

The process was inductive, in that we first performed a factor analysis of the trait measures, as a method for delineating broader constructs. The factor analysis suggested five orthogonal factors, as follows: (1) A single *Ability* factor for all the ability measures (i.e., those administered in the laboratory and the four ACT composites); (2), A broad *Anxiety* factor (consisting of Test Anxiety [from the MSLQ], Neuroticism [NEO-FFI], and Well Being, Alienation, and Stress [all from the Multidimensional Personality Questionnaire (MPQ), Tellegen, 1982]); (3) An *Achievement* factor (consisting of Achievement [MPQ], nAch [Personality Research Form (PRF), Jackson, 1967], and the Learning Strategy composite [MSLQ]); (4) A *Math/Science Self-Concept* factor (consisting of Math/Science self-concept, and Realistic and Investigative interests [Unisex Edition of the ACT Interest Inventory (UNIACT), Lamb and Prediger, 1981]; and (5) A *Motivational Self-Concept* factor (consisting of the Motivational composite [MSLQ & Motivational Skills], Self-Management Self-Concept, and Typical Intellectual Engagement [(TIE), Goff & Ackerman, 1992]).

### Structural Modeling

Hierarchical regression can illustrate the incremental variance accounted for by a series of variables, but it is a method that is well known to have results that are affected by the order of entry of predictor variables. In contrast, structural equation modeling is a technique that allows for the simultaneous estimation of the contributions of the various variables, and it allows for direct estimation of latent variables (i.e., the constructs underlying the sets of variables identified earlier). As such, using the factor-analytically derived broad constructs as a template, we attempted to develop a structural model for predicting the three task-specific self efficacy measures. Because the tasks were given in a fixed order, we also allowed for previous task self efficacy to co-determine subsequent task-specific self efficacy. As will become clear from the following discussion, we ended up with two broad models, one that does not include objective ability measures, and the other that does include such measures for predicting task-specific self efficacy.

We first identified the measurement model (the latent traits) on the basis of the exploratory factor analysis, with the constraint that no indicators were allowed to be associated with more than one latent variable. In order to better define the latent variables, those indicators not strongly related to the latent variables were dropped (Realistic Interests from Math/Science Self-Concept; Alienation from Anxiety; Reading and English ACT composites from Ability). Further, on the basis of an examination of the modification indices, error covariances between the indicators of individual latent variables were added. That is, error covariances were not allowed across different latent traits, with the exception



of the self efficacy latent variables. For the self efficacy variables, error covariances were allowed between similar indicators across the three tasks. Once an acceptable measurement model had been identified, a 'full' structural model, (i.e., one that allowed for paths between each of the latent traits and each of the task-specific self efficacy latent variables [single-headed arrows]) was specified. All non-significant paths were subsequently deleted.

#### Model 1 -- Non-Ability Traits and Self Efficacy.

In the first model, we initially allowed for multiple connections between non-ability trait constructs and self efficacy latent variables. The final model yielded a  $X^2$  (121) = 231.37, root mean squared error of approximation (RMS) = .076, goodness of fit (GFI) index = .87, Normed Fit Index (NFI) = .83, and Non-normed fit index (NNFI) = .89, all generally indicating a 'fair' fit to the data. The structural model is presented in **Figure 4**. First of all, the model is generally concordant with the inferences that were made from the examination of raw correlations between the trait measures and task-specific self efficacy. That is, there is a significant and substantial path from Math/Science Self-Concept to TRACON self efficacy, and a significant negative path from Anxiety to TRACON self efficacy. (A possible contribution to the Anxiety - TRACON self efficacy relationship may be the fact that two quizzes were administered during and after the videotape training [one-to-two days before the TRACON practice session], thus acting as a spur to evaluation apprehension.) Subsequent to the TRACON session, only TRACON self efficacy independently contributed to K-A ATC self efficacy. In a similar, but not as substantial fashion, there was also a significant path from the K-A ATC self efficacy to Noun-Pair self efficacy. The only significant path from Motivational Self-Concept was to Noun-Pair self efficacy. Although it is not entirely clear how this construct relates specifically to the Noun-Pair task, and not to the other two tasks, we see two distinct possibilities: (1) That learners perceive the Noun-Pair task as sufficiently simple to have performance determined more by effort than by ability; and (2) That by the time learners reached the Noun-Pair task, they may have developed a general sense that the tasks were 'learnable' and that motivation was the essential ingredient to success in that task. Because order of task performance was confounded with task type, it is impossible to determine whether either of these possibilities is a valid explanation.

It is also useful to note that the Achievement factor showed significant paths to both Motivational Self-Concept and Math/Science Self-Concept, but not to task-specific measures of self-efficacy. Similar to results obtained previously (Ackerman et al., 1995), these findings are consistent with the perspective suggested by Kanfer (1990) that distal trait constructs, such as achievement, influence proximal motivational constructs, such as task-specific efficacy, indirectly and through self-concept factors. The demonstration of significant paths to both domain-specific and motivational/self-regulatory self-concept factors, in conjunction with the differential influence of these self-concept factors on task-specific self efficacy suggests that future research at the level of self-concepts, rather than at the level of task performance, may ultimately prove quite useful for further delineation of motivational/self-regulatory trait influences on learning and performance.

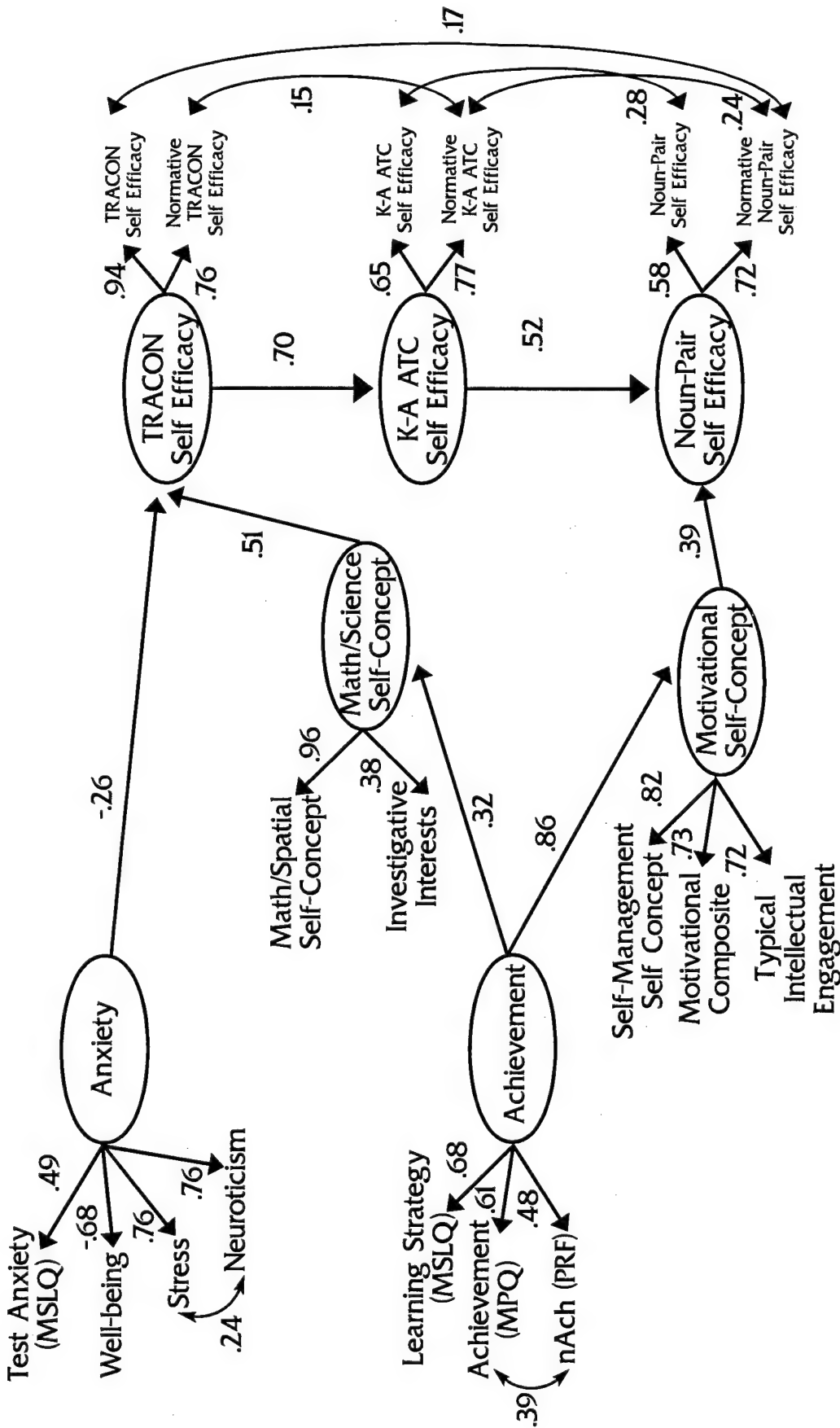


Figure 4. LISREL derived structural equation model for non-ability trait measures and self efficacy from TRACON = Terminal Radar Approach Control, K-A ATC = Kanfer-Ackerman Air Traffic Controller Task, Noun-Pair Lookup Task.

Finally, it should also be noted that there appears to be some common method variance to the procedures that were used for assessing task-specific self efficacy. Significant covariances were found for the traditional self efficacy measures, and for the three single-item normative self efficacy measures.

#### Model 2 -- Inclusion of Ability

A second set of models was developed that included the broad ability factor. The final model, shown in **Figure 5**, yielded a  $X^2(212) = 438.11$ ,  $RMS = .082$ ,  $GFI\ index = .82$ ,  $NFI = .78$ , and  $NNFI = .85$ , which indicated a similarly 'fair' fit to the data. This model, like that of a previous study (Ackerman, et al., 1995) showed that the connection between ability and task-specific self efficacy was an indirect relationship, through Math/Science Self-Concept. In addition, no connection was found between Anxiety and Ability factors. Finally, it is noteworthy that the inclusion of the Ability factor did not substantially alter the pattern of significant paths among non-ability traits and task-specific self efficacy obtained in the previous model.

In general, Model 2 indicates that initial task-specific (TRACON) self efficacy is mostly determined by Math/Science Self-Concept, which in turn, is influenced by objective ability measures. Subsequent task-specific self efficacy appears to be determined by self efficacy on prior tasks. However, there are clear differences in abilities required by the different tasks (see Kanfer & Ackerman, 1989 for the K-A ATC Task; Ackerman, 1992, Ackerman & Kanfer, 1993a, Ackerman, et al., 1995 for TRACON, and Ackerman & Woltz, 1994 for the Noun-Pair task). As such, the paths from TRACON to K-A ATC and from K-A ATC to Noun-Pair self efficacy suggest that judgements of competence may be *most* influenced by initial perceptions of the larger context of action than by the demands of specific tasks contained within that context.

#### Summary

The two LISREL models for self efficacy are consistent in showing that Math/Science Self-Concept is a major determinant of initial task-specific self efficacy, and that subsequent task-specific self efficacy is substantially determined by self efficacy for the immediately preceding task. Model 2 specifically shows the connection between objective ability measures and similar domains of self-concept -- a connection that was also demonstrated in Ackerman, et al. (1995).

Overall, the similar pattern of relations obtained in both models provides initial empirical support for the portrayal of task-specific self efficacy as an emergent property of ability and non-ability traits. Specifically, Ability and Achievement operate as distal influences on both domain-specific and broad motivational self-concepts. In turn, these self-concepts, along with Anxiety show distinctive influences on task-specific self efficacy. Whereas Math/Science Self-Concept and Anxiety are shown to be the major determinants of self efficacy for the complex TRACON learning task, previous task-specific self efficacy and

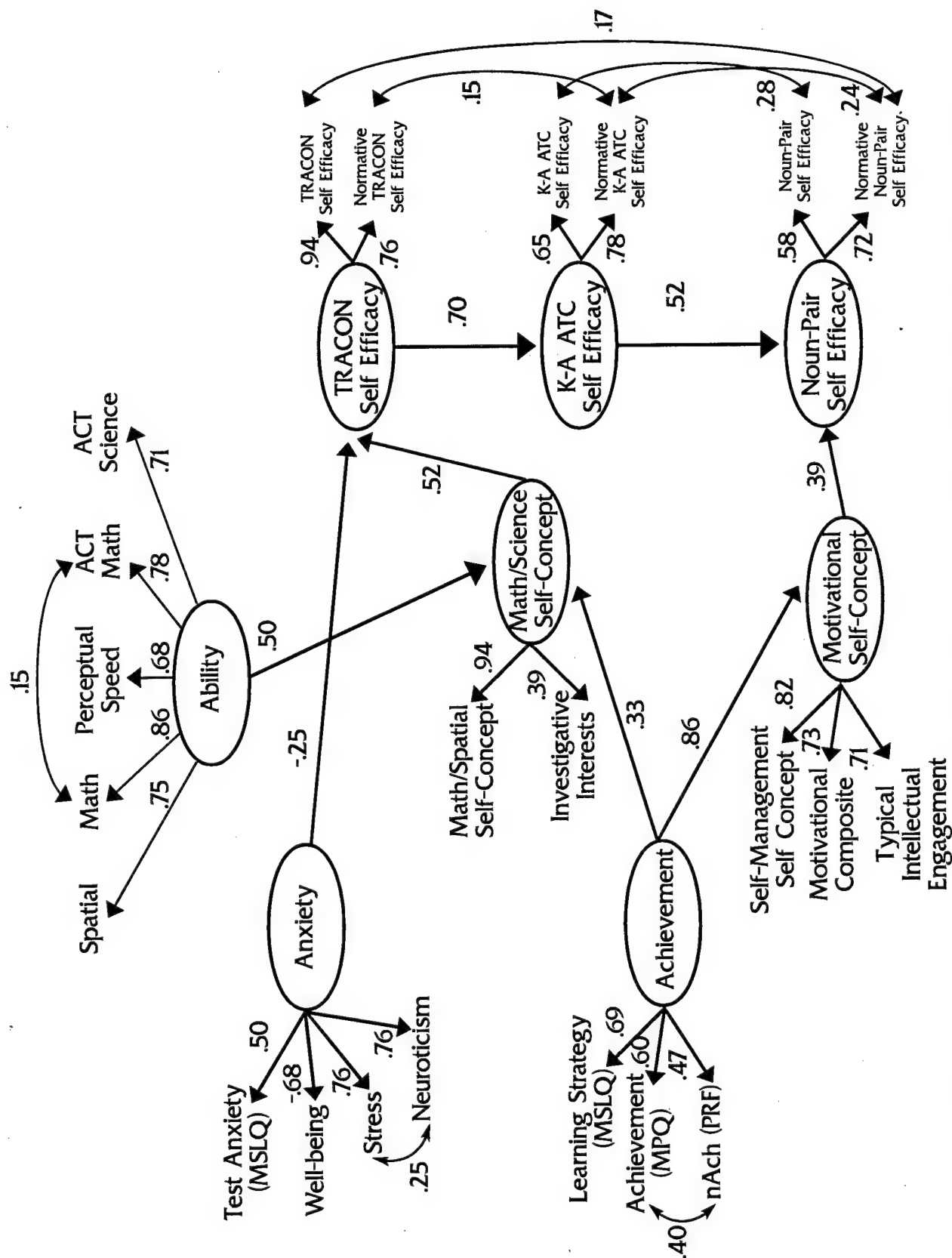


Figure 5. LISREL derived structural equation model for ability and non-ability trait measures and self efficacy from TRACON = Terminal Radar Approach Control, K-A ATC = Kanfer-Ackerman Air Traffic Controller Task, Noun-Pair Lookup Task. ACT = American College Testing.

Motivational Self-Concept were found to be the primary determinants of self efficacy for the relatively simple and tedious Noun-Pair learning task. The pattern of a significant association between Achievement and Motivational Self-Concept, but not between Ability or Anxiety and Motivational Self-Concept, provides a foundation for clarifying how and why trait measures of motivational/self-regulatory skills may show incremental predictive validity in some learning contexts.

#### *D. Aptitude - Treatment Interactions (ATIs)*

Training and Transfer Studies. One goal of this program of research was to further explore the nature of ability-performance relations as a function of treatment or training conditions. The basic rationale for this work was to manipulate the types of training that provided to learners prior to engagement of a moderately complex rule-learning and Perceptual Speed task -- namely, the K-A ATC task. By changing the nature of part-task training (e.g., the amount of part-task training, or training for near or far transfer-of-training), we could evaluate how the ability demands of the final full-task trials were changed. In our previous investigations (e.g., Ackerman, 1990; Kanfer & Ackerman, 1989, 1990, 1996), two observations appeared relevant to the importance of pre-task training on aptitude-performance relations, specifically: (a) Different amounts of pretraining resulted in changes in full-task correlations with ability; and (b) Different types of pretraining resulted in different ability - performance correlations at transfer to a full task. For example, provision of declarative knowledge training reduced ability - performance correlations in contrast to a no pretraining control, but provision of only procedural knowledge pretraining resulted in increased ability-performance correlations (i.e., procedural knowledge training in the absence of declarative knowledge about the task). Because these differences were observed across studies, there was no way to make direct comparisons of any aptitude-treatment interactions (ATIs). However, two general expectations were derived from this work (and from earlier work): (a) All other things equal, greater amounts of pretraining should result in diminished ability-performance correlations at full-task transfer; and (b) the closer the training task to the full task (nearness of transfer), the lower the ability - performance correlations at full-task transfer.

Two studies were completed. These studies are reported in detail in Goska and Ackerman (1996), but the basic design and results are described here. To provide the aptitude part of the ATI inquiry, we first assess reasoning ability (a general cognitive ability). Second, students were provided with practice in one of two training tasks, which differ in the amount of practice (Experiment 1) or type of training (Experiment 2). Finally, performance data from the criterion (transfer) task were collected. Examination of the correlations among the ability reference measures, training task performance, and criterion task performance allow for an evaluation of the hypotheses derived from Sullivan (1964) and Ackerman (1990).

In Experiment 1, we used a near-transfer task, which had previously been shown to result in reduced ability-performance correlations, in comparison to a control condition (see

Kanfer & Ackerman, 1990;  $r_{\text{ability,full task}} = .45$  ( $N = 111$ ) for control vs.  $r_{\text{ability,full task}} = .30$  ( $N = 104$ ), for a training-transfer condition). In contrast to the earlier studies, our Experiment 1 used two conditions where the amount of pretraining practice was manipulated, on the premise that greater amounts of pretraining practice would result in greater proportional transfer for the lower-ability students (and thus a reduction in the ability-performance correlation at full-task transfer).

In Experiment 2, two different tasks, one requiring the same declarative and procedural knowledge as the criterion task (a near transfer condition) and a second requiring only similar motor responses (a far transfer condition). In accordance with our hypothesis, we expected that for full-task transfer the near transfer condition would result in lower ability-performance correlations than the far transfer condition.

The criterion task used in both studies was the K-A ATC task. This task was chosen because it is procedural, moderately complex, and involves consistent stimulus-response mappings. The task also is useful because it is representative of other procedural learning tasks that are initially cognitively demanding but are capable of being well learned with practice. Commonly taught tasks of this nature range from learning to type, to drive a car, use a word processor, and the technical aspects of playing a musical instrument.

Experiment 1. Results from the first experiment (short vs. long part-task pretraining), showed transfer performance differences (especially for landings at Trial 1) as a function of training condition, which confirmed that students benefited from the three additional blocks completed in the "long pretraining" condition. Given this prerequisite, it was reasonable to evaluate the remaining hypotheses concerning differential transfer and ability-performance relations between conditions. The significant interaction between trials and training condition suggested that the advantage for the long-pretraining condition attenuated as practice progressed. Although the results concerning the relationships of general reasoning ability and full K-A ATC task performance in the two conditions did not reach statistical significance, the pattern of the correlations with the landings data was encouraging. The locus of any effect, though, would have to be found at initial transfer, as additional practice on the full K-A ATC task will diminish any relative advantages to the longer training condition. Because the null hypothesis of no significant ATI could not be rejected in this experiment, it seemed clear that a training manipulation that more clearly provided different amounts of transfer, or types of knowledge/skill transfer would be required to reveal a statistically significant ATI, in the absence of substantially larger sample sizes.

Experiment 2. In this experiment, two different types of part-task pretraining were used (the minitrial procedure used in Experiment 1, and a "procedural skills" only training, which has been used in earlier research -- see Kanfer & Ackerman, 1989). The minitrial part-task training was identified as "near" transfer (because all of the task skills were provided training), while the "procedural" part-task training was identified as "far" transfer (because only the procedural aspects of the K-A ATC task were provided training).



The performance data were congruent with that from Experiment 1 as well as in previous research (e.g., Kanfer & Ackerman, 1989, 1990). The prediction for greater general transfer for minitrial training over procedural training was supported by significant differences in mean K-A ATC landings between conditions; this is similar in form to, but larger in magnitude, than what was seen in Experiment 1. Unlike the first experiment, however, the predicted differential ability-performance relations were statistically supported for landings in Experiment 2. (For an illustration of the differential regressions, see the scatterplot in Figure 6.) The differences in slope between conditions lent support to the theory by indicating differences in the underlying ability determinants of the transfer task. That larger differences in ability-performance slope were found when larger differences in mean full-task performance were found suggests a possible linkage between amount of transfer and the underlying ability demands of task performance. That is, training conditions that substantially improve full-task transfer may also result in reduced ability demands (i.e., reduced ability-performance correlations) at transfer. For a discussion of this general issue, see Ackerman, (1990).

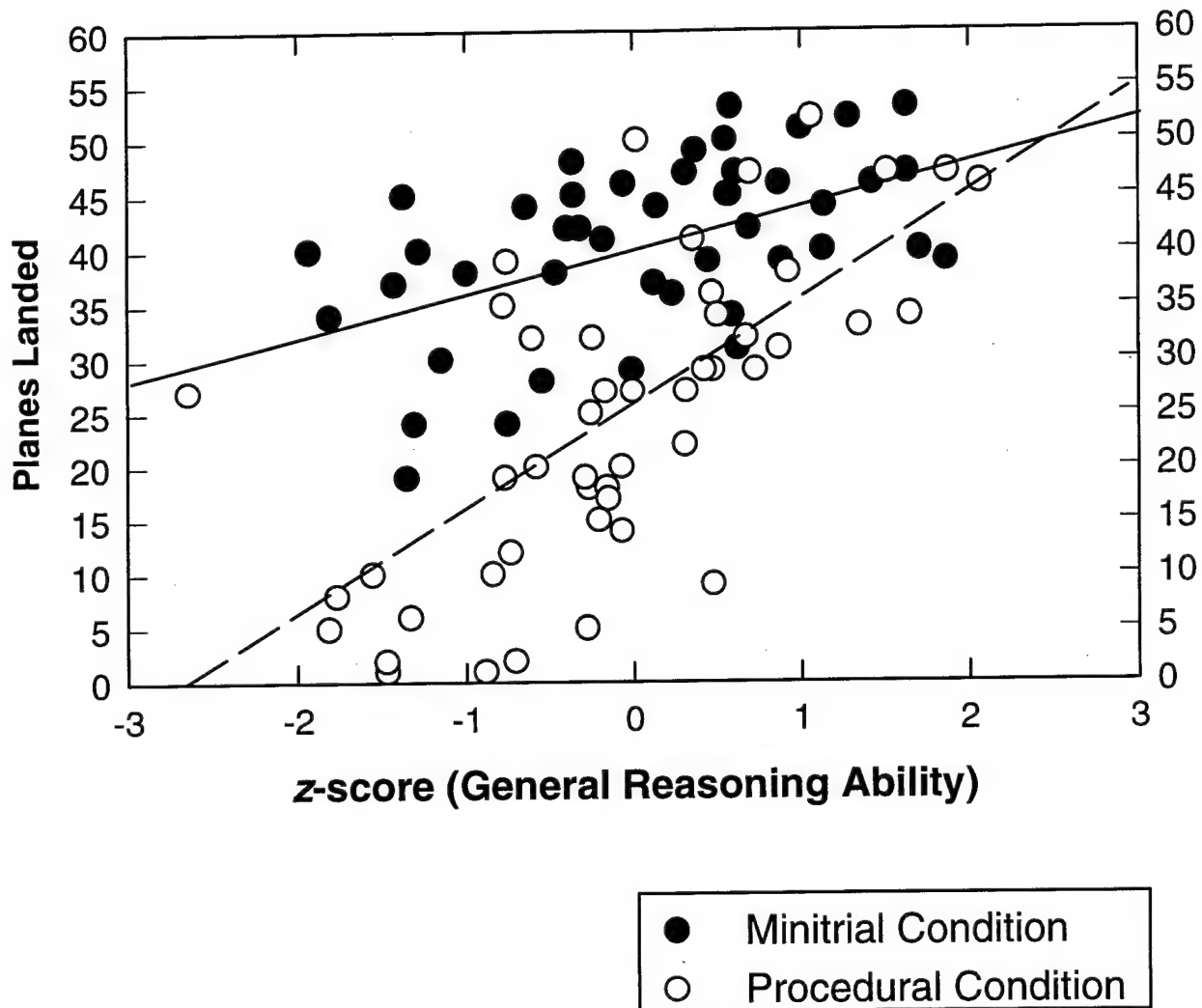
The results from these studies clearly indicated that the degree of ability-performance association in full-task transfer could be changed as a function of the type of part-task pretraining, both at initial full-task transfer (where the correlation between general ability and performance was  $r = .68$  for the procedural condition [far transfer] and  $r = .48$  for the minitrial condition [near transfer]). In fact, even after an hour of additional practice, the general ability - performance correlations still showed substantial differences ( $r = .56$  and  $.38$  for the procedural and minitrial conditions, respectively). That is, even though mean performance scores on the K-A ATC criterion task at the end of practice were similar for both groups -- K-A ATC task performance was more substantially dependent on general ability in the procedural condition than it was in the minitrial condition.

These experiments were generally supportive of the utility of the ATI approach; furthermore, they empirically demonstrated a manipulation of factors that affect both the average amount of transfer and the magnitude of ability-performance relations for the transfer task. In other words, an understanding of the relationship between certain aspects of a training task and a transfer task in terms of their respective underlying ability determinants may be used to illuminate the extent and nature of the transfer between the two.

Specifically, in these experiments, manipulations of both the similarity between training and transfer tasks and the duration of training produced differences in average transfer. Two results based on the relationships between transfer task performance and general reasoning ability were salient. First, students with a wide range of general reasoning ability benefited from the near transfer training (minitrials). Second, those of higher ability were generally better able to apply what was learned in the more distant transfer training (procedural) than were those of lower ability (such a result was suggested in Sullivan's, 1964, studies with children). In the current investigation, the result was indicated by a lower correlation between reasoning and performance for the minitrial pre-task training than for the procedural pre-task training. The more distant transfer situation was marked by requiring



Kanfer-Ackerman Air Traffic Controller Task  
(Full-task Transfer)  
from Goska & Ackerman, 1996



**Figure 6.** Scatterplot and aptitude-performance regressions of Reasoning ability and Trial 1 full-task Kanfer-Ackerman Air Traffic Controller Task Landings by training condition (minitrial vs. procedural part-task training).

new declarative knowledge to be acquired in order to perform the transfer task, and produced higher correlations with general reasoning ability. These results support a link between transfer of training and skill specificity. In light of Ackerman's (1988) model, this connection provides further insight into the mechanisms that produce transfer than is gleaned from an examination of average (i.e., across-ability) transfer alone.

Clearly, more research needs to be conducted to examine how such effects may be manifest in the larger instructional milieus. However, consistent with the results reported by Shute & Gawlick-Grendell (1992) -- although see also the review by Shute, Lajoie, & Gluck, (in press) -- these laboratory results suggest that there may be a limited effect of repeated drill-and-practice on reducing later ability-performance relations on classroom-learning tasks, especially when near transfer is considered. The more critical question that this work suggests is whether extended practice on training tasks will reduce ability-performance correlations for far-transfer situations. That is, more fundamentally, do higher-ability learners develop knowledge and skills that are generally more accessible for far transfer, or do they simply acquire knowledge and skills faster than lower-ability learners? If the former is true, then provision of additional training in a far-transfer situation will not be proportionally more beneficial to lower-ability learners. If the latter alternative is true, then far-transfer situations just require greater amounts of initial training to attenuate ability - transfer task performance correlations.

Style-of-Training Study. In a followup study (for which data analysis has not yet been completed), we examined ATIs in the context of acquiring performance on a highly-complex task, TRACON. In that study, we provided learners with one of two different training support interventions. The first type of intervention was an observational learning sequence -- where the learner watched as a task expert performed the task, and the learner was able to ask questions during the observation period. The second type of intervention was a guided learning intervention -- in this condition the participant performed the task under direct instruction by the task expert. The data are not yet fully analyzed, but the preliminary results suggest that the hands-on intervention (i.e., the learner actually performs the task under direction) is a better overall vehicle for transfer to the full TRACON task -- and that this effect transcends different levels of ability (at least for a college undergraduate sample). Such results are consistent with data obtained in simpler task environments [e.g., the K-A ATC task], but these results suggest that the power of hands-on experience should not be overstated. Indeed, such results further bring into question the general observational learning framework advocated by Bandura (1986) and others. Additional analysis and research on this topic is clearly warranted -- including an extension to a range-of-talent sample.

### **III. General Discussion/Conclusions**

Research performed under the current grant covered four several distinct, but related topics. In each of these four domains (Perceptual Speed abilities, predicting individual differences in asymptotic practice and skill retention, integration of ability and non-ability

predictors of individual differences in performance, and investigation of aptitude-treatment interactions), we validated and expanded our theoretical perspectives, and obtained substantial empirical results. These investigations provided support for the following general conclusions:

1. Perceptual Speed Abilities. Three of the seven hypothesized dimensions of Perceptual Speed abilities (Item Content, Consistency of Stimulus-Response Mappings, and Item Processing Type) were shown to have validity, from either a construct and/or criterion-related validation framework. Delineation of memory, scanning, and pattern recognition categories of perceptual speed processes appears to provide a new and useful approach to creation of new measures for prediction of individual differences in performance during the intermediate stages of skill acquisition.
2. Individual Differences in Asymptotic Performance. Ackerman's (1988) three-part theory of the cognitive ability determinants of individual differences in performance during skill acquisition (General, Perceptual Speed, and Psychomotor abilities) was generally supported through extrapolation to the acquisition of asymptotic levels of skilled performance. Even when 81% of the between-subjects variance was reduced through extended practice, ability measures selected from the theoretical framework, and administered prior to task practice, were effective predictors of individual differences in task performance. These data further support the premise that appropriate selection of ability tests can yield acceptable predictive validities for individual differences in performance at early, intermediate, and late asymptotic levels of task practice or training.
3. Individual Differences in Retention Performance. Both abilities and initial task performance are important predictors of individual differences in performance after a non-practice retention interval on tasks with substantial controlled-processing task demands. In contrast, only initial task performance and performance at the end of the initial acquisition period are significant predictors of retention performance on consistent tasks that allow for the development of automatic processing. Such results are concordant with Ackerman's (1988, 1990) theory that states retention intervals have the effect of pushing the determinants of performance back to an earlier phase of practice (in consistent information processing tasks) or remain relatively unchanged (in inconsistent information processing tasks). These results provide an additional incentive for the refinement of ability predictor measures -- as abilities appear to predictably re-assert influences after a period of skill disuse.
4. Ability - Non-ability Interactions during Skill Acquisition. In two separate studies of a wide range of ability and non-ability predictors of individual differences in performance during skill acquisition, several important non-ability predictors were found to have significant independent and interactive influences (with each other, and with objective ability measures) in predicting performance. Achievement-related motivational traits and anxiety related motivational traits were demonstrated to have

important relations with both performance and self-estimates of subjective efficacy for task performance. These promising constructs are being followed up in subsequent work on motivational traits and motivational skills by members of our research team (e.g., see Kanfer & Heggstad, in press). In addition, measures of interests, self-concept, and self-ratings of ability appear to be important mediators between objective measures of ability and individual differences in performance. Future investigations that focus on the developmental aspects of these traits appear to be especially promising.

5. Aptitude-Treatment Interactions. The demonstration of significant and stable aptitude-treatment interactions (ATIs) proved to be as slippery as has been evident in nearly 40 years of ATI research in educational and experimental contexts. However, the current research did extend our previous results in demonstrating that the nature of part-task training can have a significant effect on aptitude-performance regressions, such that more extensive and complete training can be used to reduce the general cognitive ability demands of performance during transfer to a more complex task. Such results support utility of so-called 'scaffolding' approaches to training when lower-ability learners may have difficulties in acquiring complex task performance.

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## V. Publications during the grant period

Ackerman, P. L., & Woltz, D.J. (1994). Determinants of learning and performance in an associative memory/substitution task: Task constraints, individual differences, and volition. *Journal of Educational Psychology*, 86, 487-515.

### *Abstract*

We investigated how cognitive abilities, learning task characteristics, and motivational and volitional processes combine to explain individual differences in performance and learning. We studied a substitution task over practice and discovered that students used two different strategies: a learning strategy where students focused on memorization, and a performance strategy where students persisted in scanning the items. We conducted five experiments to investigate the ability and motivational correlates of task performance in general, and strategy differences in particular. Experiment 1 demonstrated ability correlates of performance and strategy use. Experiment 2 showed that reducing task difficulty increased students' use of the learning/memory retrieval strategy. However, ability differences and stimulus characteristics were not the only determinants of strategy use under difficult task conditions. By inserting periodic memory tests (Experiment 3), we increased students' effective reliance on the learning/memory strategy and lowered task performance correlations with reasoning ability. Finally, a combination of self-focus and goal-setting interventions increased general performance levels and use of the learning/memory strategy (Experiments 4 and 5). We discuss these results, the multifaceted research strategy employed, and specific data analysis methods in terms of the general goal of developing a more comprehensive understanding of learner differences.

Ackerman, P. L., Kanfer, R., & Goff, M. (1995). Cognitive and noncognitive determinants and consequences of complex skill acquisition. *Journal of Experimental Psychology: Applied*, 1, 270-304.

### *Abstract*

Integration of multiple perspectives on the determinants of individual differences in skill acquisition is provided by examination of a wide array of predictors: ability (spatial, verbal, mathematical, Perceptual Speed), personality (neuroticism, extroversion, openness, conscientiousness, and agreeableness), vocational interests (realistic, investigative), self-estimates of ability, self-concept, motivational skills, and task-specific self-efficacy. Ninety-three trainees were studied over the course of 15 hours (across two weeks) of skill acquisition practice on a complex, air traffic controller simulation task (TRACON®). Across task practice, measures of self-efficacy, and negative and positive motivational thought occurrence were collected to examine prediction of later performance and communality with pre-task measures. Results demonstrate independent and interactive influences of distal and proximal pre-task measures in predicting task performance, and further illuminate communalities within a broad-based predictor space.

Ackerman, P. L. (1996). A theory of adult intellectual development: process, personality, interests, and knowledge. *Intelligence*, 22, 229-259.

*Abstract*

I briefly review the development of adult intelligence assessment early in this century as an upward extension of the Binet-Simon approach to child intelligence assessment. Problems with the use of IQ measures for adults are described, along with a discussion of related conceptualizations of adult intellectual performance. Prior intelligence theories that consider adult intelligence (Cattell, 1943, 1971/1987; Hebb, 1941, 1942, 1949; Vernon 1950) are reviewed. Based on extensions of prior theory and new analyses of personality-ability and interest-ability relations, a developmental theory of adult intelligence is proposed, called PPIK. The PPIK theory of adult intellectual development integrates intelligence-as-Process, Personality, Interests, and intelligence-as-Knowledge. Data from the study of knowledge structures are examined in the context of the theory, and in relation to measures of content abilities (spatial and verbal abilities). New directions for the future of research on adult intellect are discussed in light of an approach that integrates personality, interests, process, and knowledge.

Goska, R. E., & Ackerman, P. L. (1996). An aptitude-treatment interaction approach to transfer within training. *Journal of Educational Psychology*, 88, 249-259.

*Abstract*

The issues of skill specificity and transfer of training were examined from an aptitude-treatment interaction approach. The current investigations extended the Sullivan (1964) approach by using a procedural transfer task and training conditions that differ in amount of training task practice and the degree of training task similarity to the transfer task. Two experiments were conducted with 232 college students. Experiment 1 examined the effects of a length-of-training manipulation on reasoning ability and transfer task performance relationships, and on the amount of transfer. Experiment 2 evaluated the effects of two training tasks that differed in terms of similarity to the transfer task on ability-performance relationships and the amount of transfer. Results suggest that Sullivan's approach partially generalizes to the acquisition of procedural knowledge.

Kanfer, R., & Ackerman, P. L. (1996). A self-regulatory skills perspective to reducing cognitive interference. In I. G. Sarason, B. R. Sarason, & G. R. Pierce (Eds.), *Cognitive interference: Theories, methods, and findings* (pp. 153-171). Mahwah, NJ: Erlbaum.

### *Abstract*

Most people take for granted the notion that an individual's thoughts and emotions can influence task learning and performance. For example, that worrying about one's performance while taking an examination can divert attention away from the test, and thereby lower performance. Indeed, research in cognitive interference has focused largely on this negative consequence of self-regulation; that is, the detrimental influence of particular types of self-referent cognitions (e.g., worry) on test performance. However, thoughts and emotions may also exert a *positive* influence on learning and performance. Locke (see Locke & Latham, 1990 for a review) and Bandura (see Bandura, 1991 for a review) suggest that individuals who maintain a strong sense of confidence or self-efficacy during performance show task persistence and higher levels of performance. A comprehensive account of the role of thoughts and emotions must consider the conditions under which self-referent activities help *or* hinder task learning and performance.

In this chapter we use a motivational skills framework to examine the influence of self-regulatory activities on skill learning and performance. From this individual differences perspective, motivational skills refer to activities that affect the overall efficiency of self-regulation and, in turn, affect task performance. This framework builds on Kuhl's (1985) taxonomy of self-regulatory processes and proposes that individuals differ in the extent to which they develop, modify, and use two fundamental self-regulatory skills during skill acquisition namely: emotion control and motivation control. Consistent with theory and research on cognitive interference, emotion-control skills involve the use of self-regulatory processes to keep performance anxiety and other negative emotional influences (e.g., worry) at bay during task engagement. In contrast, motivation control skills involve self-regulatory processes that keep attention and effort *on* the task -- despite boredom or general satisfaction with current performance.

Rolfhus, E. L., & Ackerman, P. L. (1996). Self-report knowledge: At the crossroads of ability, interest, and personality. *Journal of Educational Psychology*, 88, 174-188.

*Abstract*

We describe an approach to adult intellect that is based on content, rather than the traditional approach, which is mostly based on process. Thirty-two scales of academic knowledge, ranging from art to physics, were rated by 202 undergraduate college students, who also completed objective ability tests and scales of vocational interests and personality. Hierarchical cluster analysis was used to identify broad knowledge domains. Analyses of knowledge clusters and individual scales were used to evaluate commonality across broad ability constructs (such as verbal and spatial ability), vocational interests (realistic, investigative, and artistic), and personality traits (typical intellectual engagement and openness). Results: (a) support broad knowledge differentiation across fluid and crystallized abilities; (b) show a coherent pattern of positive correlations between arts and humanities knowledge with typical intellectual engagement and openness personality traits; and (c) show correlations between math and physical sciences knowledge with Realistic and Investigative interests. Implications for the study of adult intelligence and prediction of academic performance are discussed.

Ackerman, P. L. (In press). Personality, self-concept, interests, and intelligence: Which construct doesn't fit? *Journal of Personality*.

*Abstract*

Evaluation of overlap among correlational construct families provides a basis for cross-fertilization in each of the four separate individual-differences domains. This paper provides some new insights on E. L. Thorndike's claim that superiority in one trait implies superiority in other traits. Differentiating developments and methodological differences among correlational domains of inquiry are reviewed from modern investigations of personality, self-concept, interests, and intelligence. Sources of overlap between personality and other trait families are discussed, and four trait complexes are reviewed: social, clerical/conventional, science/math, and intellectual/cultural. Implications of the trait-complex approach and challenges to integrative research approaches to applied problems are presented.

Ackerman, P. L., & Heggestad, E. D. (In press). Intelligence, personality, and interests: Evidence for overlapping traits. *Psychological Bulletin*.

*Abstract*

We review the development and refinement of the modern paradigm for intelligence assessment and application, and consider the differentiation between intelligence-as-maximal performance and intelligence-as-typical performance. Prior and current theories of intelligence, personality, and interest are reviewed as a means to establishing potential overlap. Consideration of intelligence-as-typical performance provides a basis for the evaluation of intelligence-personality relations and intelligence-interest relations. Evaluation of relations among personality constructs, vocational interests, and intellectual abilities provides evidence for communality across these traditionally disparate constructs from the personality domain and domains of Holland's model of vocational interests. An extensive meta-analysis of personality-intellectual ability correlations is provided, along with a review of interest-intellectual ability associations. Four trait complexes were identified that cross domains of ability, personality and interests: Social, Clerical/Conventional, Science/Math, and Intellectual/Cultural.

## VI. Presentations during the grant period

- Ackerman, P. L. (1993, June). *Cognitive and perceptual speed ability determinants of complex skill acquisition*. Invited address presented at the 1993 meetings of the North American Society for the Psychology of Sport and Physical Activity, Brainerd, MN.
- Ackerman, P. L. (1993, August). *Individual differences in skill acquisition: From basic to applied psychology*. Invited "Distinguished Scientific Award for Early Career Contribution to Psychology" address presented at the 1993 annual meeting of the American Psychological Association, Toronto, Canada.
- Ackerman, P. L. (1993, August). *The future of computerized aptitude testing: "Back to Binet" or "On to Nintendo?"* Symposium paper presented at the 1993 annual meeting of the American Psychological Association, Toronto, Canada.
- Kanfer, R. (1994, February). *Motivational/self-regulatory influences in skill acquisition*. Invited colloquium to Department of Psychology, Virginia Polytechnic Institute, Blacksburg, VA.; and to Department of Psychology, Rice University, Houston, TX.
- Ackerman, P. L. (1994, March). *Cognitive abilities and skill learning: A framework for selection, intervention, and the study of intellect*. Invited address presented to the Department of Management and Organizations, University of Iowa, Iowa City, IA.
- Kanfer, R. (1994, July). *Motivation, self-regulation, and self-efficacy: A skills perspective*. Invited address, American Psychological Society meetings, Washington, D.C.
- Ackerman, P. L. (1994, July). *Theory and applications of individual differences in skill acquisition: Writing the new textbook for selection*. Symposium paper presented at the 1994 International Congress of Applied Psychology. Madrid, Spain.
- Ackerman, P. L. (1994, September). *Psychomotor abilities: Exploration and integration*. Invited colloquium presented to the U.S. Air Force Armstrong Laboratory/Project LAMP; San Antonio, Texas.
- Ackerman, P. L., & Kanfer, R. (1994, November). *Determinants of asymptotic performance in a perceptual/motor skill*. Paper presented at the 1994 annual meeting of the Psychonomic Society. St. Louis, MO.
- Kanfer, R. (1994, November). *Cognitive and non-cognitive determinants of performance and skill acquisition*. Invited colloquium, AT&T Measurement and Selection Division, Morristown, NJ.
- Ackerman, P. L. (1994, November). *Cognitive and non-cognitive determinants and consequences of complex skill acquisition*. Invited colloquium presented to the Department of Educational Psychology, University of Iowa, Iowa City, IA.
- Ackerman, P. L. (1995, February). *Intelligence as process and knowledge: An integration for adult development and application*. Invited address presented at the Southeastern Center Conference on Aging and Skill Acquisition; Destin, FL.
- Kanfer, R. (1995, February). *Cognitive and self-regulatory processes in adult skill acquisition*. Invited colloquium, Department of Psychology and Combined Program in Education and Psychology, University of Michigan, Ann Arbor, MI.



- Ackerman, P. L. (1995, March). *Integrating individual differences in psychomotor abilities: Common factors and prediction*. Invited address presented to the U.S. Air Force Armstrong Laboratory/Project LAMP Mini-Conference on Psychomotor Abilities; San Antonio, Texas.
- Kanfer, R. (1995, March). *Motivational skills: A self-regulatory perspective*. Nineteenth Annual Gaudet Memorial Lecture Series colloquia, Stevens Institute of Technology, Hoboken, NJ.
- Kanfer, R., & Ackerman, P. L. (1995, April). *Self-regulation and complex skill acquisition: Evaluating two perspectives*. Symposium paper presented at the 1995 annual meeting of the American Educational Research Association.
- Goff, M., Rolfhus, E. L., & Ackerman, P. L. (1995, April). *Incremental prediction of learning performance: Self-concept and domain-specific knowledge*. Symposium paper presented at the 1995 annual meeting of the American Educational Research Association.
- Ackerman, P. L. (1995, August). *Personality, intelligence, motivation, and interests: Implications for overlapping traits*. Invited address (Division 15) presented at the annual meeting of the American Psychological Association, New York.
- Kanfer, R. (1995, October). *Motivation: A trait perspective*. Invited talk, Society of Organizational Behavior, Madison, WI.
- Ackerman, P. L. (1996, January). *Intelligence, personality, interests, and knowledge: Implications for overlapping traits and a theory of adult intellectual development*. Invited colloquium presented to the U.S. Air Force Armstrong Laboratory; San Antonio, Texas.
- Ackerman, P. L. (1996, March). *Intelligence, personality, interests, and knowledge: Overlapping traits and a theory of adult intellectual development*. Invited colloquium presented at the Department of Psychology, University of Washington: Seattle, Washington.
- Kanfer, R. (1996, March). *Motivational dynamics in skill learning*. Invited talk, Personnel and Human Resources Research Group annual meeting, Gainesville, FL.
- Kanfer, R. (1996, May). *Workplace motivation and self-management: New approaches*. Invited talk, Minnesota Psychological Association annual meetings, Minneapolis, MN.
- Ackerman, P. L. (1996, June). *Personality and the attitude of the learner*. Invited address presented to General Motors Research/Hughes Training workshop "The Future of Learning." Arlington, Texas.
- Ackerman, P. L. (1996, August). *Psychomotor/perceptual speed abilities: New measurement techniques and trait overlap*. Symposium paper presented at the 1996 annual meeting of the American Psychological Association.
- Ackerman, P. L. (1996, August). *Theory of adult intellectual development: Process, personality, interests, and knowledge*. Symposium paper presented at the 1996 annual meeting of the American Psychological Association.